A CAHNERS PUBLICATION
INTERNATIONAL EDITION
MAY 10, 1990

EDN®

25 MAY 1990

SPECIAL ISSUE:
Analog Technology

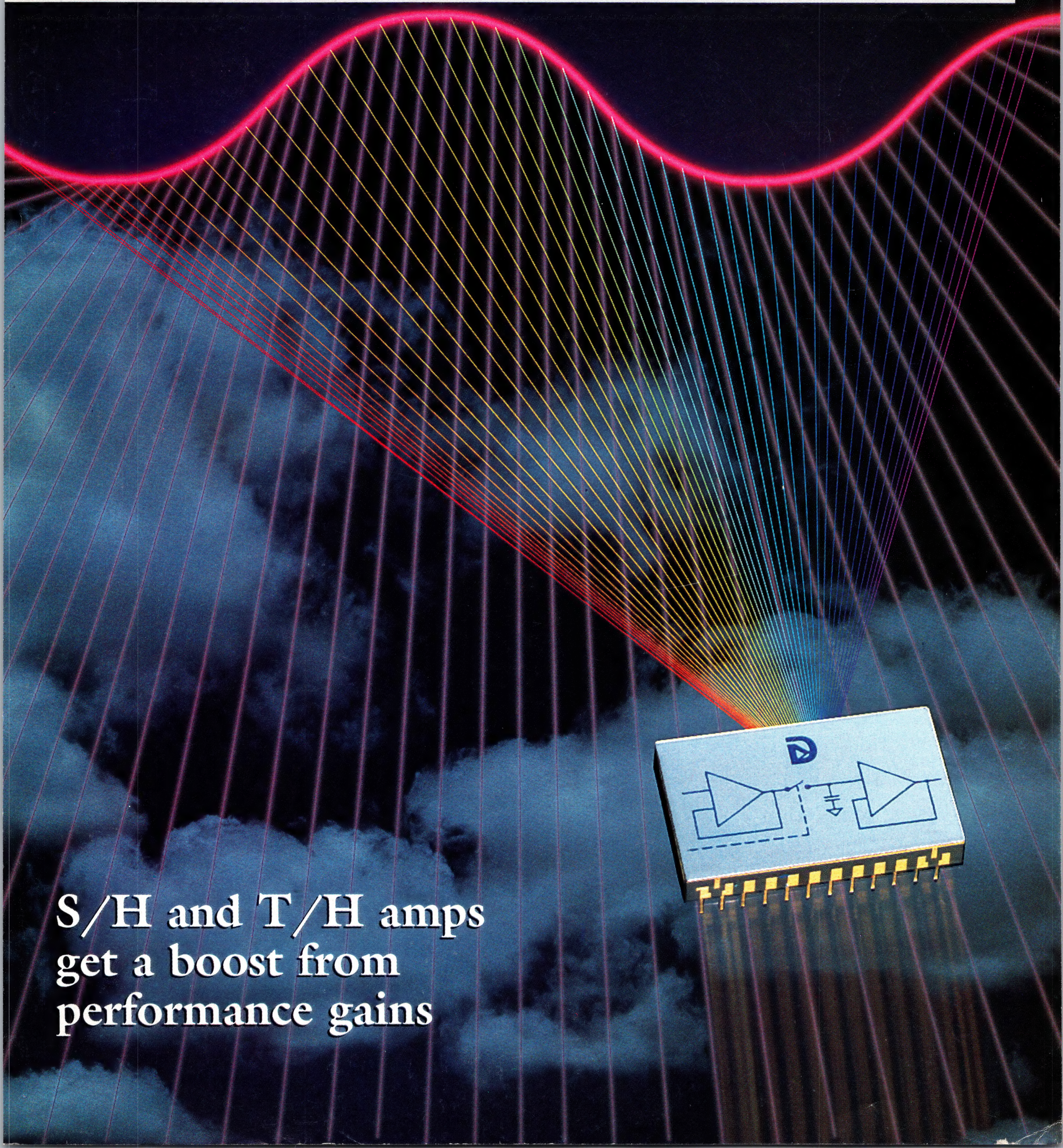
DC current sources—Pt 3

Troubleshooting analog circuits—the epilogue

Handheld DMMs

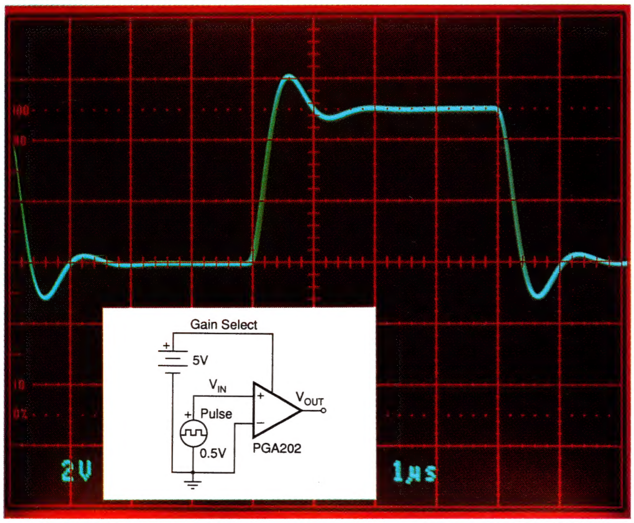
EDN's All-Star PC—Pt 5

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS

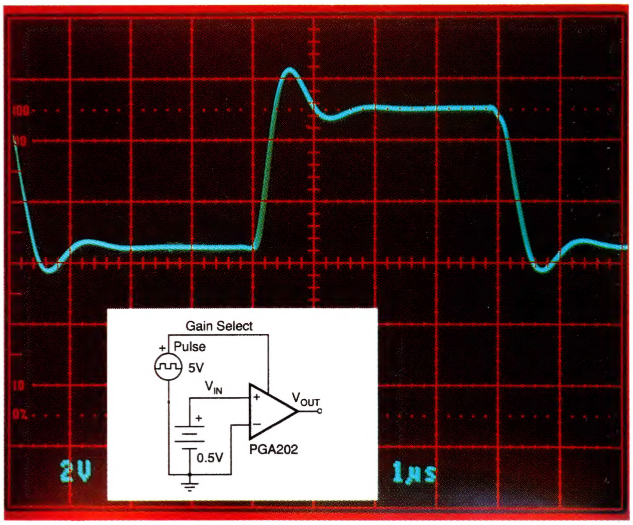


S/H and T/H amps get a boost from performance gains

Change Gain In 2µs.



PGA202 response to SIGNAL change.



PGA202 response to GAIN change.

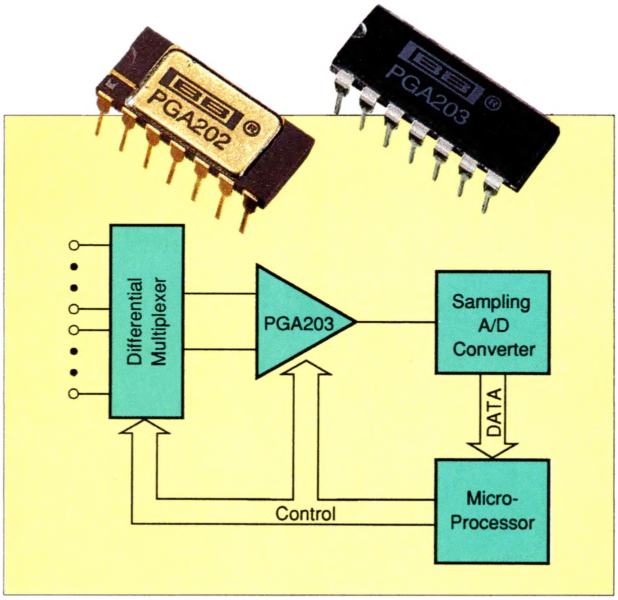
Low Cost Programmable Gains

Our new PGA202/203 monolithic instrumentation amps provide fast, digitally programmable gain changes at very low cost. A two-bit "word" is used to select gains of 1, 10, 100, or 1000 for the PGA202, and 1, 2, 4, or 8 for the PGA203.

They feature true differential inputs and full common-mode input ranges, and their advanced transconductance circuitry keeps bandwidth nearly constant with gain. Both accept TTL- or CMOS-compatible inputs for easy microprocessor interfacing.

Key Specifications

- 2µs settling time (0.01%)
- 50pA max input bias current
- 0.012% max nonlinearity
- 80dB min CMRR
- 0/+70°C, –25/+85°C temp ranges
- 14-pin Ceramic or Plastic DIPs



PGA203 in an 8-channel differential-input data acquisition system.

100s of Uses

PGA202 and 203 have been optimized for rapid-scanning data acquisition systems and high source impedance applications, including remote instrumentation and test/measurement equipment. The comprehensive data sheet contains detailed diagrams for a variety of useful circuits: 8-channel differential data acquisition systems; programmable current sources; low noise differential amps with gains of 100, 200, 400, and 800; and many more.

For more information on these fast, flexible gain blocks, contact your local Burr-Brown sales representative for data sheets and samples.

Burr-Brown Corp.
P.O. Box 11400
Tucson, AZ 85734 U.S.A.
FAX (602) 741-3895.

BURR-BROWN®

BURR-BROWN INTERNATIONAL SALES OFFICES: AUSTRIA 0222/62 63 71; **BELGUIM** (02) 521.86.50; **FRANCE** (1) 39 54 35 58; **ITALY** (02) 58.01.05.04; **JAPAN** (03) 586-8141; **NETHERLANDS** 020-6010041; **SWEDEN** 0760-93010; **SWITZERLAND** (01) 7240928; **UNITED KINGDOM** (0923) 33837; **WEST GERMANY** 0711/7704-0.

CIRCLE NO. 112

STD ROM

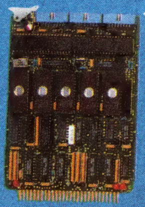
A New ROM-based Development Standard from Ziatech

Put Your STD System to Bed

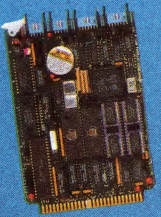
STD ROM streamlines the development of embedded applications. It combines Borland's Turbo Debugger with Ziatech's VIRTUAL TARGET INTERFACE and STD ROM LOCATE to provide an environment for easily ''ROMMING'' Microsoft C and Turbo C applications.

Single Board Selection

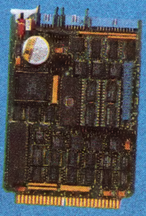
*Ziatech offers the best selection of single board computers in the business. These compact, cost-effective computers are compatible with existing STD Bus products and the new **STD 32** Bus introduced by Ziatech.*



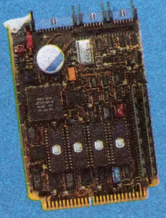
8088



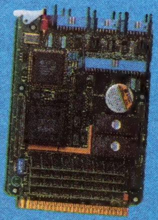
V20



V40



V50



80386SX

Not Just Another STD Bus Company

Our on-line technical support, systems engineering courses, guaranteed product availability and superior documentation have made Ziatech the premier STD computer company.

FREE Demo and Data

STD ROM can be on your doorstep within days. Call today to arrange a free demonstration. STD ROM and Ziatech are ready to serve your embedded application needs.

ZIATECH
CORPORATION

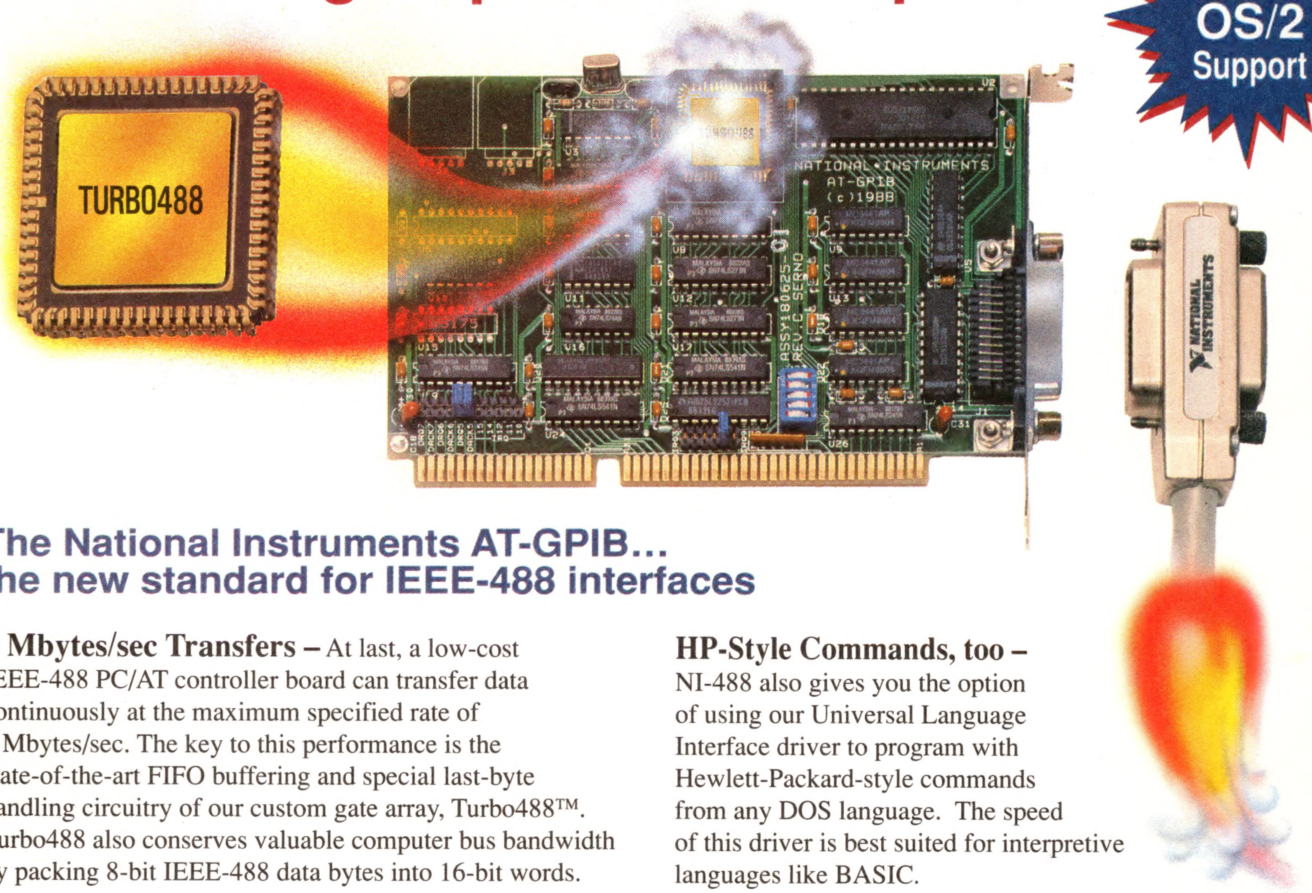
FAX (805) 541-5088
Telephone (805) 541-0488

© Copyright 1989 by Ziatech Corporation. All rights reserved.
Product names of other companies may be trademarks of those companies.

Circle No. 110

Maximum IEEE-488 Performance for Your High-Speed AT Computer

Now with OS/2 Support

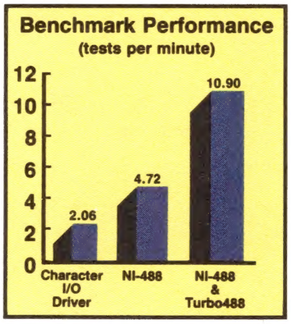


The National Instruments AT-GPIB...
the new standard for IEEE-488 interfaces

1 Mbytes/sec Transfers – At last, a low-cost IEEE-488 PC/AT controller board can transfer data continuously at the maximum specified rate of 1 Mbytes/sec. The key to this performance is the state-of-the-art FIFO buffering and special last-byte handling circuitry of our custom gate array, Turbo488™. Turbo488 also conserves valuable computer bus bandwidth by packing 8-bit IEEE-488 data bytes into 16-bit words.

Hardware Speed – By moving time consuming software functions into hardware, the Turbo488 significantly reduces the overhead of a software driver too. The combination of the AT-GPIB and our streamlined NI-488 driver gives you the power needed for today's high-speed digitizers.

Industry Standard NI-488 Software – NI-488 has high-level routines that transparently handle IEEE-488 protocol and buffered DMA transfers. These routines can be used with any popular language and are the perfect match for the structured, hierarchical style preferred by users of high-speed, compiled languages such as C and Pascal.



HP-Style Commands, too – NI-488 also gives you the option of using our Universal Language Interface driver to program with Hewlett-Packard-style commands from any DOS language. The speed of this driver is best suited for interpretive languages like BASIC.

A Sound Investment – You can still run your existing NI-488 programs yet automatically take full advantage of the Turbo488. If you're just getting started, our interactive instrument control and menu-driven configuration utilities will get you up and running in no time.

Support – Your relationship with National Instruments does not end when you purchase our products. A staff of applications engineers is always a free phone call away. Demand the best IEEE-488 controller available…give us a call today at **(800) IEEE-488**.

Ask for a *FREE* Catalog

Turbo488 technology is standard on our boards for Micro Channel and Macintosh computers

NATIONAL INSTRUMENTS®
The Software is the Instrument™
6504 Bridge Point Parkway
Austin, Texas 78730
(512) 794-0100
(800) IEEE-488

NIHON NATIONAL INSTRUMENTS K.K. (JAPAN) • (03) 788-1921 • **NATIONAL INSTRUMENTS OF FRANCE** (1) 4865-3370 • **NATIONAL INSTRUMENTS OF ITALY** (2) 4830-1892 • **NATIONAL INSTRUMENTS UNITED KINGDOM** (6) 355-23545 • **ARGENTINA** (1) 46-5776 • **AUSTRALIA** (2) 736-2888 • **AUSTRIA** (316) 391-804 • **BELGIUM** (2) 466-8199 • **CANADA** (416) 890-2010, (613) 596-9300, (514) 747-7878, (403) 295-0822, (604) 988-2195 • **DENMARK** (42) 251-122 • **FINLAND** (358) 0 351-1800 • **GREECE** (1) 361-1283 • **HONG KONG** (2) 0426-2707 • **INDIA** (2) 346-6571, (11) 683-6571 • **INDONESIA** (21) 414-838 • **IRELAND** (3) 846-661414, (3) 427-2282, (44) 236-40840 • **ISRAEL** (3) 324-298 • **KOREA** (2) 776-5340 • **MEXICO** (905) 523-7886 • **THE NETHERLANDS** (7) 099-6360 • **NORWAY** (2) 53-1250 • **PAKISTAN** (42) 879-927 • **PORTUGAL** (1) 545-313 • **SINGAPORE** (65) 336-4713 • **SOUTH AFRICA** (11) 787-0473 • **SPAIN** (1) 555-8112 • **SWEDEN** (8) 792-1100 • **SWITZERLAND** (6) 552-8949 • **TAIWAN/THE REPUBLIC OF CHINA** (2) 703-6280 • **THAILAND** (2) 234-9330 • **VENEZUELA** (2) 959-4036 • **WEST GERMANY** (89) 80-7081

Circle No. 111

We put ourselves in your shoes. That's why we have 33 different function generators.

One of them is bound to fit.

Because for more than twenty-five years, Wavetek has been building function generators for all shapes and sizes of needs.

If you're performance minded and want high frequency output, synthesized accuracy or GPIB programmability, we have your size ... up to 50 MHz for example.

Others may want comfort and economy, and for them we have some of the easiest-to-operate, lowest-cost instruments available. After all, simple operation has been a Wavetek hallmark ever since we introduced the world's first solid state function generator.

Some people look for the stylish touches, like amplitude, frequency or phase modulation, pulse outputs and variable phase. They'll find them here.

And for the truly independent thinkers, we have arbitrary generators that let you design your own waveforms.

So does this mean you should always look to Wavetek whenever you need a function generator? As they say, if the shoe fits...

For the Wavetek Function Generator that fits, call (619) 279-2200, or fax (619) 565-9558.

WAVETEK®

Circle 38 for Literature

Circle 37 for Demonstration

© Copyright 1989 Wavetek Corporation

Orbit puts engineering prototypes within reach.

Now you can cut NRE expense and save valuable time on engineering prototype runs just by using a little foresight. Foresight, Orbit's new multi-project wafer processing service, puts the engineering prototypes you need within reach. In record time. And at a record low cost.

Orbit's new Foresight accommodates generic CMOS processes with feature sizes down to 1.2 microns with maximum die sizes of 300 mils on a side. Getting in on a run is as easy as supplying a database tape by our monthly start date.

Available processes:

- Single Poly/Single Metal
- Double Poly/Single Metal
- Single Poly/Double Metal
- Double Poly/Double Metal

Don't wait until high NRE costs and slipped deadlines put you in a bind. Design rules and information on Orbit's new Foresight service are within reach today by contacting Foresight Marketing or the international rep nearest you. Orbit Semiconductor, Inc. 1230 Bordeaux Drive. Sunnyvale, CA 94089. FAX (408) 747-1263. Or call (800) 331-4617. In California (800) 647-0222 or (408) 744-1800.

ORBIT SEMICONDUCTOR, INC.

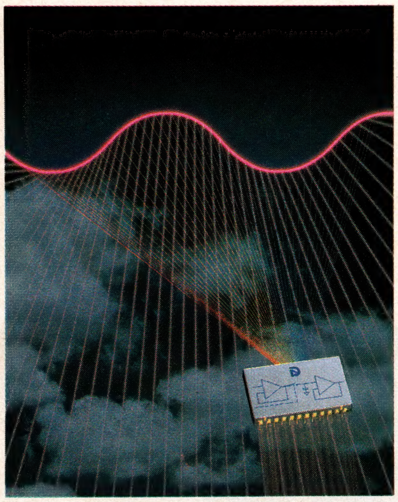
A subsidiary of Orbit Instrument Corporation.

What others promise, we guarantee.

CIRCLE NO. 41

INTERNATIONAL REPRESENTATIVES: *Canada* (514)481-3313 – *U.K.* Phone (0372) 377779, Tlx 897628 S.G. U.K.-G, Fax (0372) 376848 – *Europe* Phone (06031) 61076, Tlx 6031 948, FAX (06031) 61788 – *Australia* Phone (8) 223 5802, Tlx UNIVAD AA89141, Fax (8) 224 0464.

EDN® Magazine Edition
Volume 35, Number 10
May 10, 1990
ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS



On the cover: *Performance improvements keep sample-and-hold and track-and-hold amplifiers viable in the face of A/D-converter advances. See the Special Report on pg 72. (Photo courtesy Datel Inc)*

SPECIAL ISSUE: ANALOG TECHNOLOGY

SPECIAL REPORT

S/H and T/H amplifiers 72

Discrete S/H and T/H (track-and-hold) amplifiers remain afloat in today's sea of data-acquisition design options. Improvements in accuracy, speed, and integration continue to make S/H and T/H amps a high-performance choice for applications that require the flexibility of discrete designs.—*Anne Watson Swager, Associate Editor*

EDN's All-Star PC Project—Part 5 91

After months of development, chronicled in four previous articles, it's time for the All-Star PC to do more than run operating systems, benchmarks, and utility programs. It's time to do real work by running engineering software.—*Steven H Leibson, Senior Regional Editor*

INNOVATION™
Driving Electronic Technology Into The Next Century

DESIGN FEATURES

Designer's guide to precision dc current sources—Part 3 107

The final installment of this 3-part series shows how to control current sources digitally. It also explains why the last component you want to use as a digitally controlled current source is the first one you're likely to think of—a current-output D/A converter. *—Jerald Graeme, Burr-Brown Corp*

Pease's pointers rouse readers: Letters to Bob 119

Bob Pease's series on troubleshooting generated myriad letters from readers—far more than we could do justice to in our Signals and Noise column. Because so many of the letters contained worthwhile troubleshooting tips and amusing personal anecdotes, EDN's editors decided to collect some of the best letters into an article, along with Bob's replies and interjections.

Continued on page 7

EDN®(ISSN 0012-7515) is published 49 times a year (biweekly with 2 additional issues a month, except for February, which has 3 additional issues and July and December which have 1 additional issue) by Cahners Publishing Company, A Division of Reed Publishing USA, 275 Washington Street, Newton, MA 02158-1630. Terrence M McDermott, President; Frank Sibley, Senior Vice President/General Manager, Boston Division; Jerry D Neth, Senior Vice President/Publishing Operations; J J Walsh, Senior Vice President/Finance; Thomas J Dellamaria, Senior Vice President/Production and Manufacturing; Ralph Knupp, Vice President/Human Resources. Circulation records are maintained at Cahners Publishing Company, 44 Cook Street, Denver, CO 80206-5800. Telephone: (303) 388-4511. Second-class postage paid at Denver, CO 80206-5800 and additional mailing offices. POSTMASTER: Send address corrections to EDN® at the Denver address. EDN® copyright 1990 by Reed Publishing USA; Ronald G Segel, Chairman and Chief Executive Officer; Robert L Krakoff, President and Chief Operating Officer; William M Platt, Senior Vice President. Annual subscription rates for nonqualified people: USA, $109.95/year; Canada/Mexico, $135/year; Europe air mail, $165/year; all other nations, $165/year for surface mail and $250/year for air mail. Single copies are available for $10. Please address all subscription mail to Ellen Porter, 44 Cook Street, Denver, CO 80206-5800.

BPA ABP

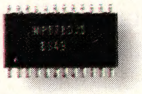
At last, an A/D Video Flash Converter that goes down easy.

A sure cure for "board bulge," the Micro Power Systems MP8780 is less than half the size of its 20MHz 28-pin counterparts. Encapsulated in a tiny 24-pin "skinny" DIP, it delivers 15MHz performance at only 300mW. Just what you need to optimize speed, power and packaging for video digitizing and imaging.

Now you can get full-flash performance at half-flash power. Operating at only 300mW, your system is less demanding on your power supply. Less prone to failure. And less sensitive to thermal problems.

Which one would you rather swallow?

But this tiny monolithic 8-bit CMOS device also gives you more.

More design flexibility. Its 10MHz input bandwidth and adaptable input structure allows you to customize the input voltage range to the exact requirements of your application. More accuracy. Its ±½ LSB enables us to guarantee accuracy to 8-bit performance. More package options. It's available in surface mount.  And more resistance to ESD, with a tolerance exceeding 4000V.

Take the high performance "board bulge" cure. Call us now at 408/562-3660 to receive your free Flash Pack including short form catalog and flash data sheets. Or fax us at 408/562-3605.

We'll be glad to tell you more about the MP8780, or any other device in our complete line of standard high-speed flash converters and 8-16 bit A/D and D/A converters.

Micro Power Systems
3100 Alfred St., Santa Clara, CA 95054

© 1990 Micro Power Systems

CIRCLE NO. 42

Continued from page 5

EDN Magazine Edition®

May 10, 1990

Rugged, handheld DMMs *provide a valuable measure of circuit performance despite electrical and physical abuse (pg 55).*

EDN magazine now offers Express Request, a convenient way to retrieve product information by phone. See the Reader Service Card in the front for details on how to use this free service.

Express Request

Use Spice to solve problems on high-speed digital boards 133

As digital clock rates reach 50 MHz and head toward 100 MHz, high-frequency effects such as crosstalk and transmission-line reflections can create serious problems. Microwave simulators can help you diagnose and eliminate potential trouble spots before you commit your design to hardware.—*Octavius Pitzalis, Jr and Thomas M Reeder, EEsof Inc*

TECHNOLOGY UPDATE

Handheld DMMs shine despite ill treatment 55

Vendors now offer ruggedized and electrically robust handheld DMMs that survive misuse and rough handling. But to obtain valid measurements, you will need to study the DMM's limitations. —*Brian Kerridge, European Editor*

EDITORS' CHOICES

Graphical VHDL source-level debugger 65
Data-compression chip 67

PRODUCT UPDATE

Switched-mode power-supply IC 68

DESIGN IDEAS

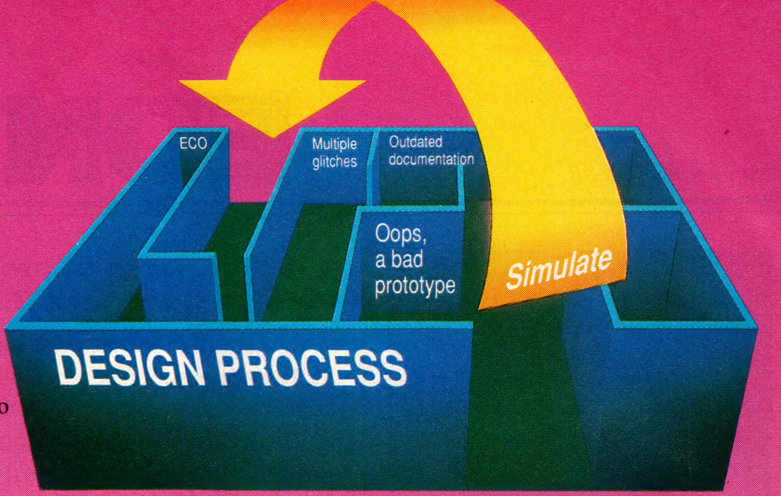
Capacitor boosts amplifier bandwidth 147
TMS32010 routine finds phase 148
Programmable pulser takes 5-nsec steps 150
Step-recovery diodes sharpen pulses 154
Software debounces µP inputs 156
Calculators find resistor values 160
C routine sets bit groups 160

Continued on page 9

Cahners Publishing Company, A Division of Reed Publishing USA ☐ Specialized Business Magazines for Building & Construction ☐ Manufacturing ☐ Foodservice & Lodging ☐ Electronics & Computers ☐ Interior Design ☐ Printing ☐ Publishing ☐ Industrial Research & Technology ☐ Health Care ☐ and Entertainment. Specialized Consumer Magazines: ☐ American Baby ☐ and Modern Bride.

OrCAD Answers Your Questions About

Logic Simulation



Q: Why simulate?

A: To save time.

The ideal development cycle is schematic to prototype to production. Simulation dramatically decreases the dreaded loop of schematic to prototype to schematic to prototype to schematic to...

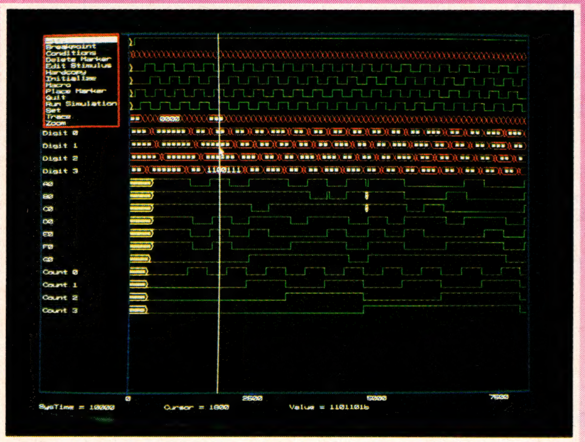
A: To save money.

If your design goes through several iterations, is the documentation still accurate? Suddenly your time and budget are being spent on laying in patches, not producing.

A: To make you look good.

Your schematic is supposed to be the best answer to someone else's design problem. Think of how great you'll look when you present a solution with no glitches, timing violations or other problems.

Verification of your design doesn't have to be handled at the prototype stage (or worse yet, the production stage).



```
SysTime = 10000     Cursor = 1800     Value = 1101101b
```

OR8839I

You need a digital simulator that helps you find timing violations and design anomalies before you spend time and money on prototypes. The result: fewer iterations, a shorter design cycle, a more reliable product and getting the project right.

Why OrCAD/VST?

A: OrCAD/VST enables you to interactively verify your design as it develops. A netlist from OrCAD's powerful Schematic Design Tools is all that's required to get started.

A: OrCAD/VST features a user interface similar to OrCAD/SDT III, including easy-to-use menu driven commands and powerful keyboard macros. Your valuable time is spent designing and testing rather than trying to learn a new system.

A: OrCAD/MOD extends OrCAD/VST to PLDs. A set of PLD Simulation Modeling Tools, OrCAD/MOD produces models of PLDs for OrCAD/VST to use in simulation of the larger circuit in which the PLD will operate.

A: OrCAD/VST offers unsurpassed performance on a PC. Independent benchmark tests have hailed OrCAD's logic simulator as superior to other simulators costing 20 times as much.

- Event driven, 12-state functional simulator
- 16,000+ events/sec. on an 8 MHz AT
- 65,000+ events/sec. on a 20 MHz 386
- Over 14,000 gate capability without additional memory
- Logical analyzer display format (virtual screen displays 50 channels)
- User selectable min. and max. displays
- Includes component models of TTL, ECL, CMOS, Memory devices & utilities for creating custom models
- OrCAD's excellent support: technical staff, 24 hour BBS, 1 year free product updates, and a trained sales and support network.

Call or write today for your Demo Disk and brochure.

OrCAD®
Systems Corporation
3175 NW Aloclek Drive
Hillsboro, Oregon 97124
(503) 690-9881

If you would like more information about this or any other OrCAD product, contact your local OrCAD representative.

AUSTRIA
Dahms Elektronik
0316/64030-0
Fax: 64030-29

ITALY
BRM Italiana
0117/710636
TEL: 011/771.00.10
FAX: 011/771.01.98

BELGIUM
INEX
(02) 649.99.91
Fax:(02)649.27.92

ITALY
MicroData Systems
0187/966123
Fax:0187/988322

DENMARK/NORWAY
NordCAD
98 17 32 99
Fax: 98 17 37 41

SPAIN
Next-For S.A.
504 02 01
Fax: 504 00 69

UK
ARS Micro-systems
(0276) 685005
Fax:(0276) 61524

SWEDEN
Technology Partners
(468)790 97 75
Fax: (468)16 77 86

FINLAND
Elektrotel OY
(358 0)754-3122
Fax: 754-2593

SWITZERLAND
Logmatic AG
056/83 38 38
Fax: 056/83 38 40

FRANCE
ALS Design
(331) 46 04.30.47
Fax: 48 25.93.60

W. GERMANY
Compware, GmbH
4940/81 80 74
Fax:4940/81 10 37

CIRCLE NO. 43

Continued from page 7

VP/Publisher
Peter D Coley
VP/Editor/Editorial Director
Jonathan Titus
Managing Editor
Joan Morrow
Assistant Managing Editor
Susan L Rastellini
Special Projects
Gary Legg
Home Office Editorial Staff
275 Washington St, Newton, MA 02158
(617) 964-3030
Tom Ormond, *Senior Editor*
Charles Small, *Senior Editor*
Jay Fraser, *Associate Editor*
John A Gallant, *Associate Editor*
Michael C Markowitz, *Associate Editor*
Dave Pryce, *Associate Editor*
James P Scanlan, *Associate Editor*
Julie Anne Schofield, *Associate Editor*
Dan Strassberg, *Associate Editor*
Anne Watson Swager, *Associate Editor*
Chris Terry, *Associate Editor*
Kathleen M Vejvoda, *Associate Editor*
Helen McElwee, *Senior Copy Editor*
Susan Bureau, *Copy Editor*
Christine McElvenny, *Senior Production Editor*
Gabriella A Fodor, *Production Editor*
Brian J Tobey, *Production Editor*
Editorial Field Offices
Steven H Leibson, *Senior Regional Editor*
Boulder, CO: (303) 494-2233
Doug Conner, *Regional Editor*
Atascadero, CA: (805) 461-9669
J D Mosley, *Regional Editor*
Arlington, TX: (817) 465-4961
Richard A Quinnell, *Regional Editor*
Aptos, CA: (408) 685-8028
Maury Wright, *Regional Editor*
San Diego, CA: (619) 748-6785
Brian Kerridge, *European Editor*
(603) 630782
(St Francis House, Queens Rd,
Norwich, NR1 3PN, UK)
Contributing Editors
Robert Pease, Don Powers,
Bill Travis
Editorial Coordinator
Kathy Leonard
Editorial Services
Helen Benedict, Nicky Woodlock
Art Staff
Ken Racicot, *Senior Art Director*
Chinsoo Chung, *Associate Art Director*
Cathy Madigan, *Staff Artist*
Production/Manufacturing Staff
Andrew A Jantz, *Production Supervisor*
Deborah Hodin, *Production Assistant*
Lisa K Mariano, *Production Assistant*
Michele R Weinberg, *Production Assistant*
Diane Malone, *Composition*
Director of Art Department
Joan Kelly
Norman Graf, *Associate*
VP/Production/Manufacturing
Wayne Hulitzky
Director of Production/Manufacturing
John R Sanders
Business Director
Deborah Virtue
Marketing Communications
Anne Foley, *Promotion Manager*

EDITORIAL 49

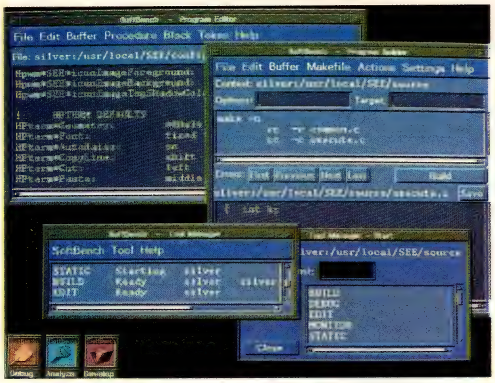
Help us choose the year's most innovative products and engineer or engineering team.

NEW PRODUCTS

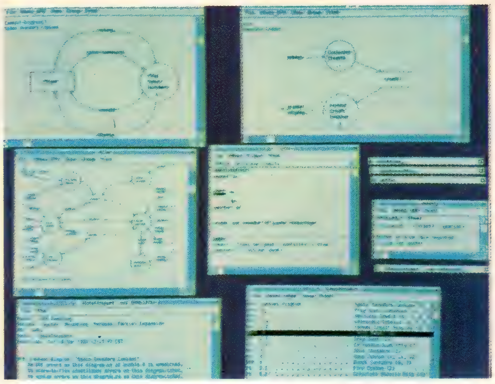
Components & Power Supplies 169
Integrated Circuits 180
CAE & Software Development Tools 190
Computers & Peripherals 200
Test & Measurement Instruments 210

DEPARTMENTS

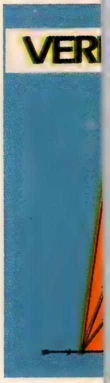
News Breaks 21
Signals & Noise 31
Calendar 40
Literature 222
Career Opportunities 239
Leadtime Index 244
EDN's International Advertisers Index 246

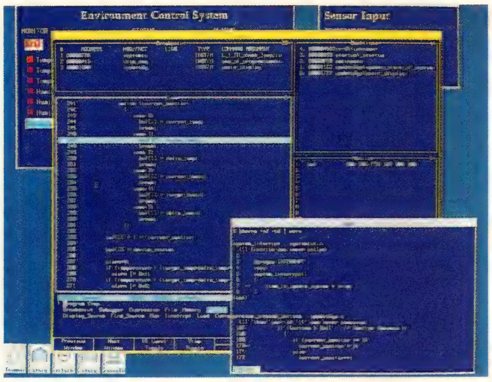

File Edit Buffer Procedure Block Token Help
File Edit Buffer Makefile Actions Settings Help
SoftBench Tool Help
Debug
Analyze
Develop

HP SoftBench: A software development environment with an integrated set of program development and integration platform tools.



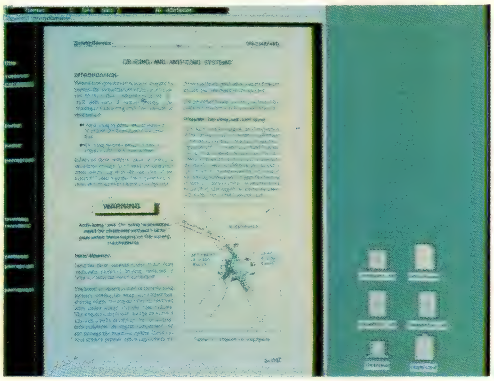
Cadre Teamwork: A family of tools that implement system analysis and software design methodologies.



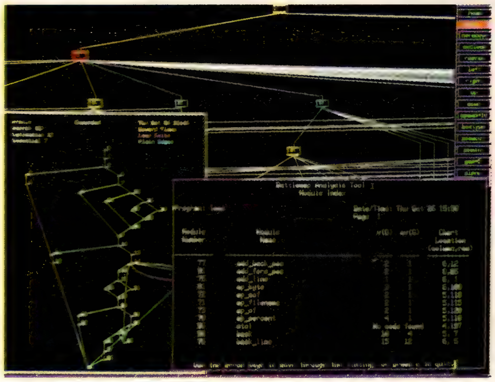


HP AxDB Debugger: Displays microprocessor code, stack backtrace, and variables. Test coverage window shows statements not executed during test.

Best CA

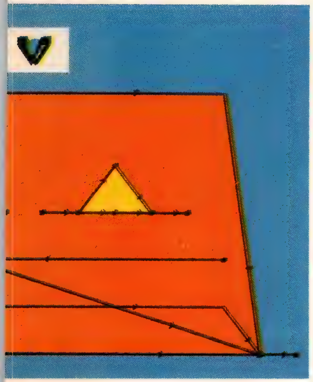


Interleaf Technical Publishing Software: A documentation software and management system that features integrated text and graphics.

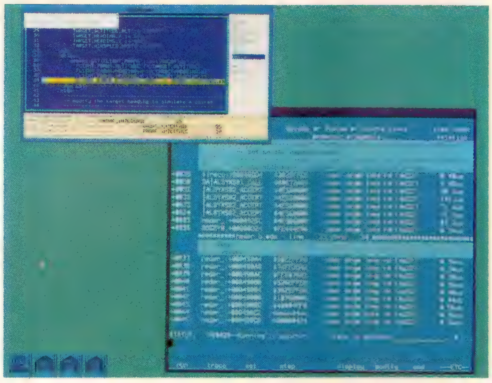


McCabe Test Tools: An automated software testing and reverse engineering application.

© 1990 Hewlett-Packard Company CPEG920



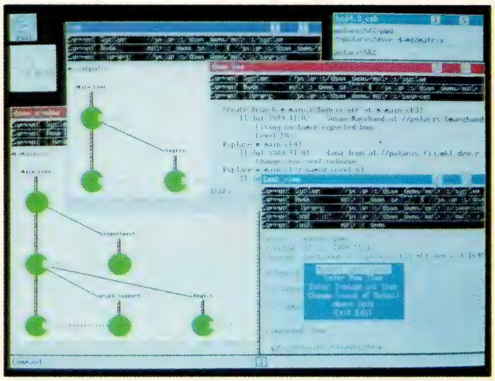
Verilog LOGISCOPE: Automated testing of source code analysis for reverse engineering.



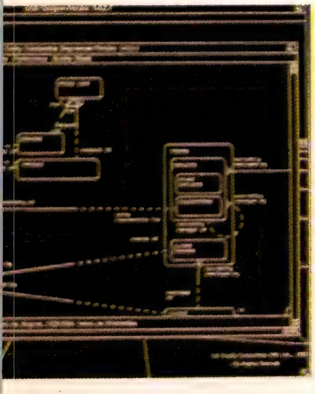
Ada: A development environment that allows real-time symbolic debugging, available from multiple vendors.

i-Logix Statemate: Allows dynamic analysis of complex systems long before design and implementation.

SE scenario.

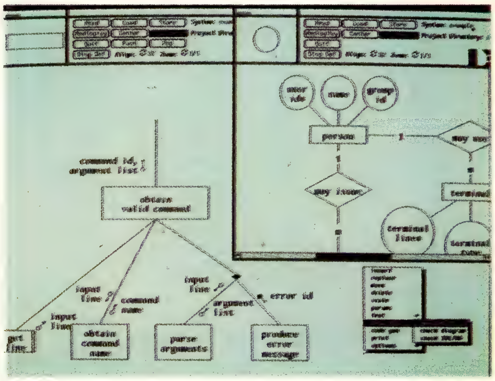


Apollo DSEE: Offers unequaled software development support for complex, team-oriented projects.



ORACLE: An application for structured, computer-assisted development of systems solutions.

Frame FrameMaker®: Easy-to-use text, graphics, and layout tools for documentation.



IDE Software Through Pictures®: Integrated tools for improving software quality that emphasize systems analysis and software design.

Your software release dates are continually postponed. Defects are discovered late in your development process. And your team can't find contemporary solutions to existing problems.

Hewlett-Packard has a better way.

With the HP CASEdge program and our software suppliers, we offer a broad selection of development tools for the software engineering industry. And a strong commitment to helping your team find, evaluate, and implement the right software engineering tools and best practices for the task at hand.

HP CASEdge solutions speed the automation of specification, design, implementation, debugging, and maintenance. And decrease development costs while getting your products to market faster.

For your next design project, choose the vendor with the best CASE scenario. Call HP today at 1-800-752-0900, Ext. 219X.

There is a better way.

HEWLETT PACKARD

CIRCLE NO. 44

Bruxelles (02-2) 771 91 42 • Geneva (02) 2880025 • Hanover area (0511) 73 60 85 • Hong Kong (5) 8654525 • London area (0483) 740440 • Manchester area (0925) 828008 • Milano (02) 3533241 • München (089) 41 14-0 • Osaka (06) 243-3250 • Paris (1) 49 75 10 10 • Seoul (02) 784-7598 • Singapore (65) 348 1188 • Stockholm (08) 733 03 50 • Stuttgart (0711) 62 33 77 • Taiwan (02) 7213393 • Tokyo (03) 345-8241 • Latin America, Fort Lauderdale, Florida/U.S.A. Tel: (305) 484-8600 Tlx: (510) 955-4261 amd ftl • World Network and SUPERNET are trademarks of Advanced Micro Devices, Inc. © 1989 Advanced Micro Devices, Inc.

Fiber Op

With FDDI, it'll seem like your data gets there before it's sent. Because FDDI is ten times faster than Ethernet.

And if you thought FDDI was just a dream, you can open your eyes. Now there's an FDDI chip set—just ask any of the companies bringing systems to market.

The chip set is called SUPERNET™ and it's a lot more than just a few sleek chips. Because AMD brings more knowledge and expertise to FDDI systems than any other component manufacturer.

In fact, AMD founded the Advanced Networking Group—a meeting of the minds of the most important mainframe, workstation, board, network, semiconductor and software companies. They're getting together to insure compliance and interoperability so FDDI will be a wise choice for your customers.

AMD was part of setting the standards long before the Advanced Networking Group. (We've been on the ANSI standard committee since its inception.)

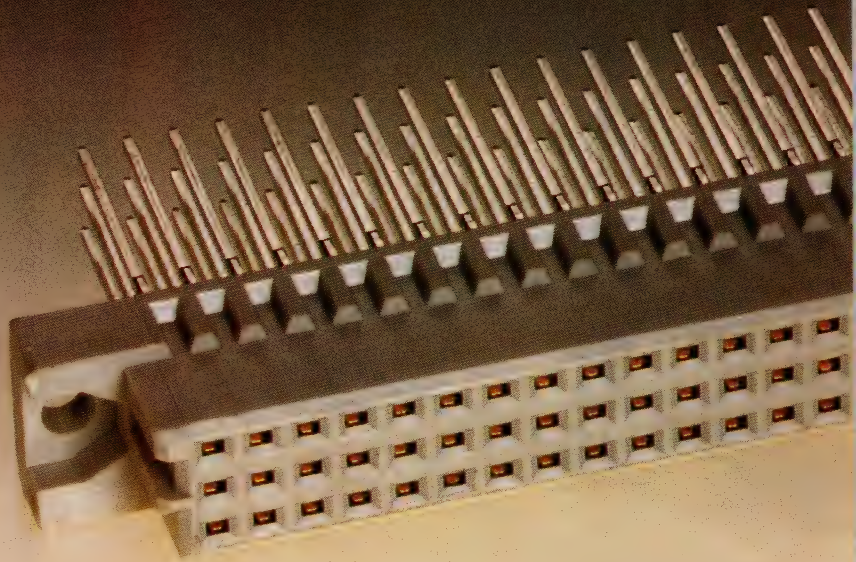
More good news. Because SUPERNET based systems meet standards, they're interoperable with FDDI systems from other vendors.

If you've been waiting to design an FDDI system, don't let another second slip away. Contact us to find out more about FDDI and the World Network.™

Advanced Micro Devices

For more information write "FDDI" on your letterhead and mail to: (In Europe) AMD Mail Operations, P.O. Box 4, Westbury-on-Trym, Bristol BS9 3DS United Kingdom
(In Asia) Advanced Micro Devices Far East Ltd., Rm. 1201-2 Harcourt House, 39 Gloucester Road, Hong Kong. Attn: Andrew Ng. (In Japan) Advanced Micro Devices Japan Ltd., Shinjuku Kokusai Bldg.,
6-6-2 Nishi-Shinjuku, Shinjuku-ku, Tokyo 160, Japan.

CIRCLE NO. 45



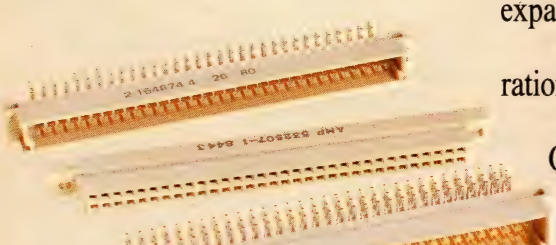
The AMP Eurocard. Don't leave

The AMP Eurocard connector is now manufactured around the world.

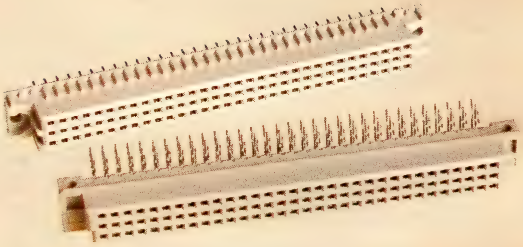
So all the benefits you expect from AMP—selection, delivery, specials—are that much closer to home, wherever you are.

In the U.S., for example, production covers types C, R, B, and Q. Plus half sizes and expanded 3-row versions.

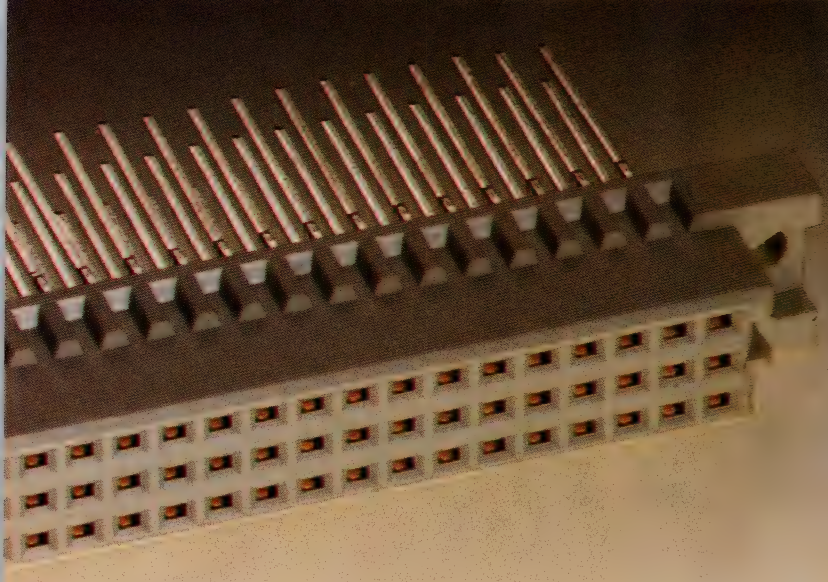
You choose the tail configuration you need—including our ACTION-PIN compliant pins. Our latest housing design allows solderless insertion with standard 'flat rock' tooling.



Available nearby: a variety of AMP Eurocard connector sizes and styles for packaging flexibility in DIN 41612 and IEC 603-2 applications.



AMP Eurocard connectors and packaging are designed with automation in mind, too, with high-temp housings, close tolerance tails. Position data are identical on through-hole and



Made worldwide.
home to get it.

surface-mount housings, for easy tooling transition to SMT designs.

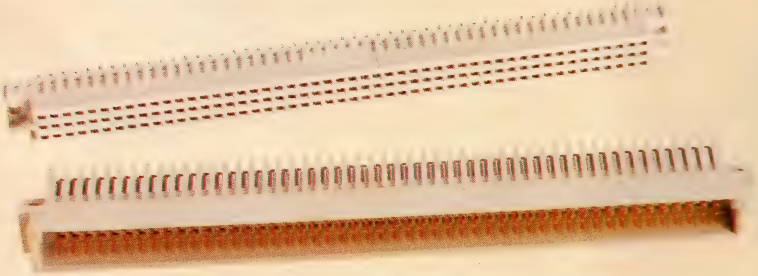
And the support you need to take advantage of all this—from technical expertise to prototypes, to specials, to full systems packaging support—is right in one place, right around the corner.

For technical information or product literature, call 1-800-522-6752. AMP Incorporated, Harrisburg, PA 17105-3608.

For characterized backplane assemblies, contact AMP Packaging Systems, Inc., P.O. Box 9044, Austin, Texas 78766, (512) 244-5100.

THIS IS AMP TODAY.

AMP

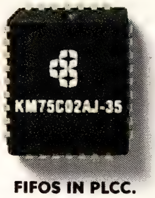


AMP and ACTION-PIN are trademarks of AMP Incorporated.

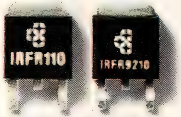
SAMSUNG
NOW

WHEN IT COMES
THERE'S NOTHING

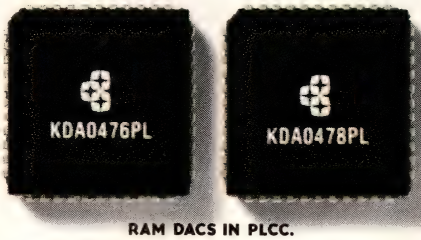
Depth may not be the first thing you look for in parts designed to stay on the surface. But when you consider the advantages posed by a truly in-depth offering of surface-mount parts, down through a number of advanced product families—all consistently available from a single supplier—



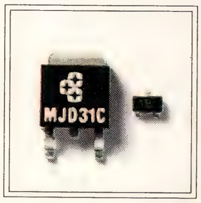
FIFOS IN PLCC.
Samsung FIFOs include the fastest high-density parts made, and the industry's first programmable-flag FIFOs. Both are available in PLCC.



MOSFETS IN D-PACK.
Unsurpassed in ruggedness, Samsung MOSFETs include 16 sought-after N-channel and P-channel parts in D-PACK.



RAM DACS IN PLCC.
The new Samsung high-speed 6-bit and 8-bit RAM DACs are now available, and both are offered in PLCC.



TRANSISTORS IN D-PACK AND SOT-23.
The world's No. 2 producer of transistors, Samsung offers more than 100 SOT-23s and 15 part types in D-PACK.

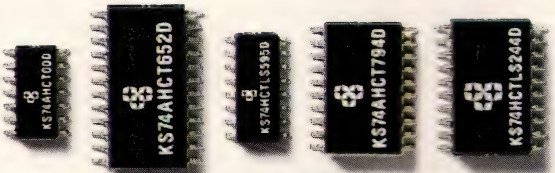
MICROPROCESSOR PERIPHERALS IN PLCC.
The fastest family in the industry, all 17 of our peripherals are available now in PLCC.

TO SURFACE MOUNT, LIKE DEPTH.

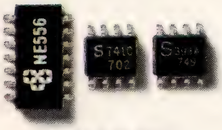
it begins to look rather attractive. Day in and day out, you can get surface-mount parts from Samsung. For information, write to Product Marketing, Samsung Semiconductor, 3725 North First Street, San Jose, CA 95134. Or call 1-800-669-5400, or 408-954-7229.

SRAMS IN SOIC AND SOJ.
Our 8Kx8 and 32Kx8 slow SRAMs are both available in SOIC packaging.

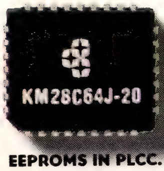
DRAMS IN SOJ AND PLCC.
From 64K to 256K to 1Mb and 4Mb, in numerous organizations and many modes, every Samsung DRAM is offered in surface mount.



LOGIC IN SOIC.
We offer every part in our advanced CMOS logic families, HCTLS and AHCT, in SOIC surface mount. 276 parts in all.



LINEAR IN SOIC.
Samsung makes one of the world's broadest families of linear devices, including many parts in SOIC.

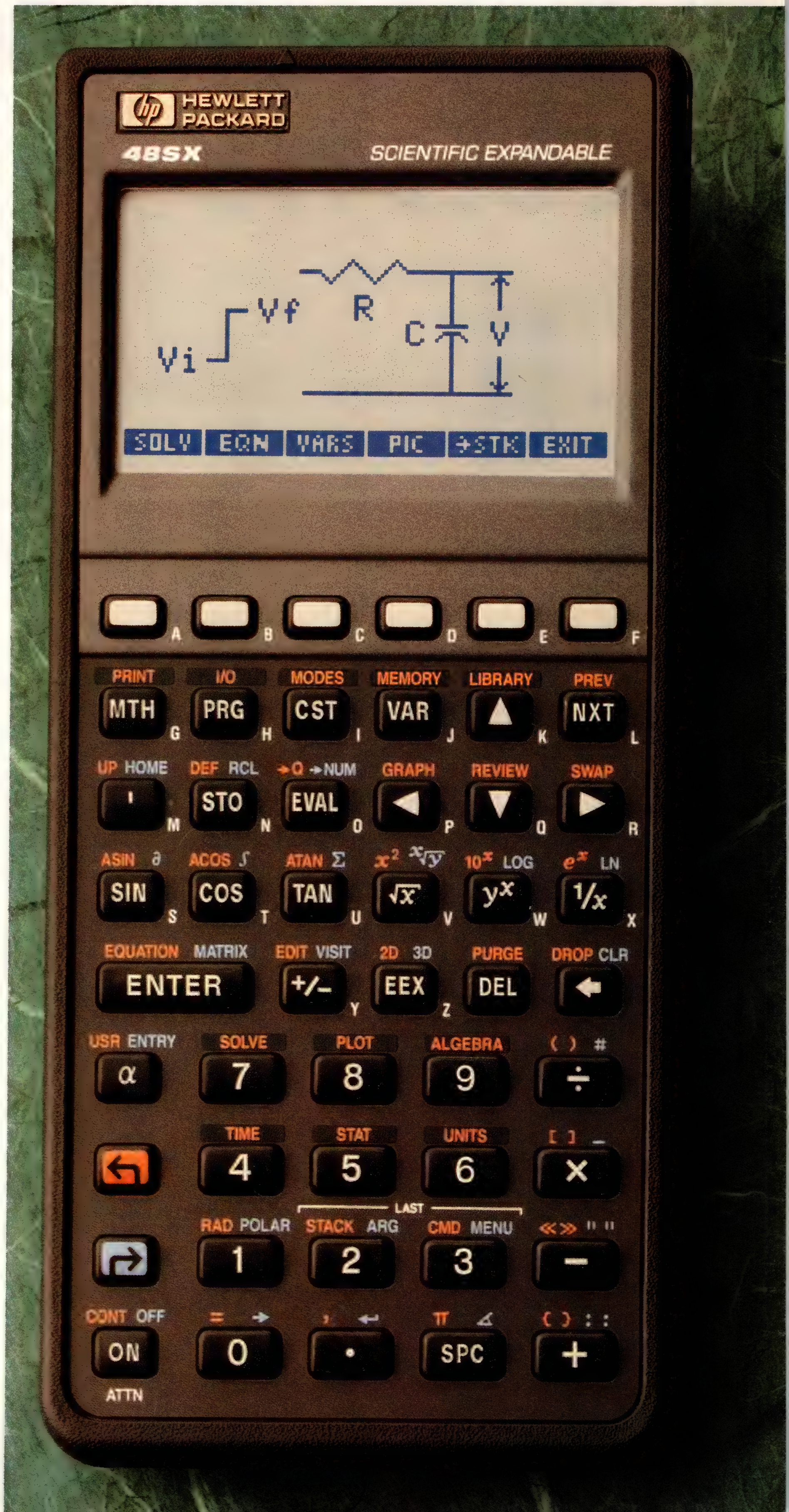


EEPROMS IN PLCC.
Our 16K, 64K, and 256K CMOS standard EEPROMs are offered in PLCC surface mount, and our serial 256-bit and 1K chips are offered in SOIC.

SAMSUNG
Semiconductor

Products shown larger than actual size. *© Samsung Semiconductor, Inc., 1990.*

The HP 48SX. The most powerful calcul



The new HP 48SX is that far ahead of the times. It has over 2100 built-in functions, including scores you've never seen in a calculator before. And probably won't see in any other calculator for years.

But functions only tell part of the story. The HP 48SX streamlines the entire sequence of problem-solving, from problem statement to final answer. Every step is linked. And everything you used to pull from reference books or work out on paper is now at your fingertips.

In the optional HP Solve Equation Library application card, you'll find more than 300 scientific and engineering equations. Most important, they're integrated and displayed, often graphically, in ways that make your work faster, easier and more accurate than ever before.

Even unit management is now entirely automatic, as the calculator tracks and converts units in 16 categories, such as force, mass and energy. For even greater power and customization, you can download programs from your PC. Add plug-in cards and memory.

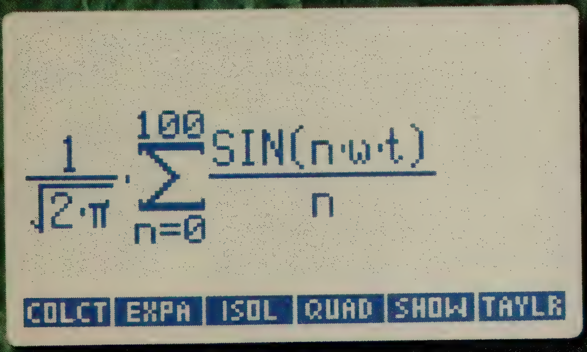
Obviously an ad can only skim the surface. So we've created a PC demo disk and facts kit to give you an in-depth view.

To receive them, send us the coupon. Or, for a hands-on demo, visit your local retailer. (Check the Yellow Pages for retail locations.) You'll get a powerful look into the future.

There is a better way.

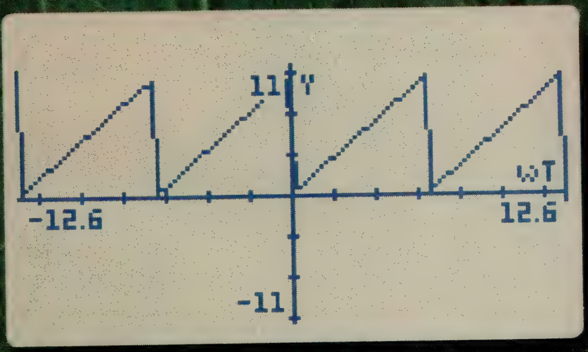
HEWLETT PACKARD

tor to come along in the next ten years.

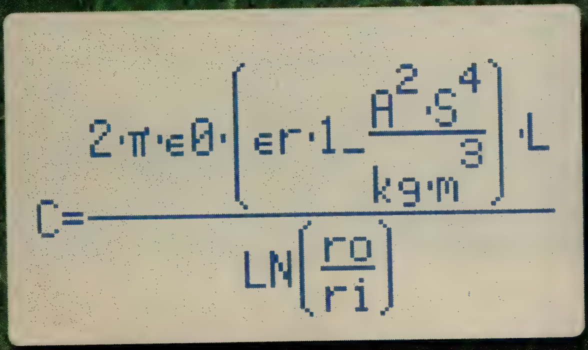


$$\frac{1}{\sqrt{2\cdot\pi}}\cdot\sum_{n=0}^{100}\frac{SIN(n\cdot\omega\cdot t)}{n}$$

Fourier series of triangle wave form.
The HP 48SX lets you enter and read equations just as you would write them in a notebook. No more translating into computer language. It's a first for a calculator.



Same Fourier series, different form.
Traditional function plots of equations don't always show you the data in the proper form. That's why the HP 48SX provides a variety of plot types, including function, polar, scatter plots, truth and parametric. Without any programming.



$$C=\frac{2\cdot\pi\cdot\varepsilon0\cdot\left(\varepsilon r\cdot 1\_\frac{A^2\cdot S^4}{kg\cdot m^3}\right)\cdot L}{LN\left(\frac{ro}{ri}\right)}$$

Capacitance of a cylindrical capacitor.
No more tedious, mistake-prone unit conversions. The HP 48SX automatically converts 148 different units in a totally paperless process. You can even add your own units.

CIRCLE NO. 48

Send for your free demo disk and facts kit.

I have an:
☐ IBM or IBM compatible PC
☐ Apple Macintosh Computer

My disk size is:
☐ 3½"
☐ 5¼"

NAME ________ TITLE ________
COMPANY ________
ADDRESS ________
CITY ________ STATE ________ ZIP ________
TELEPHONE ________

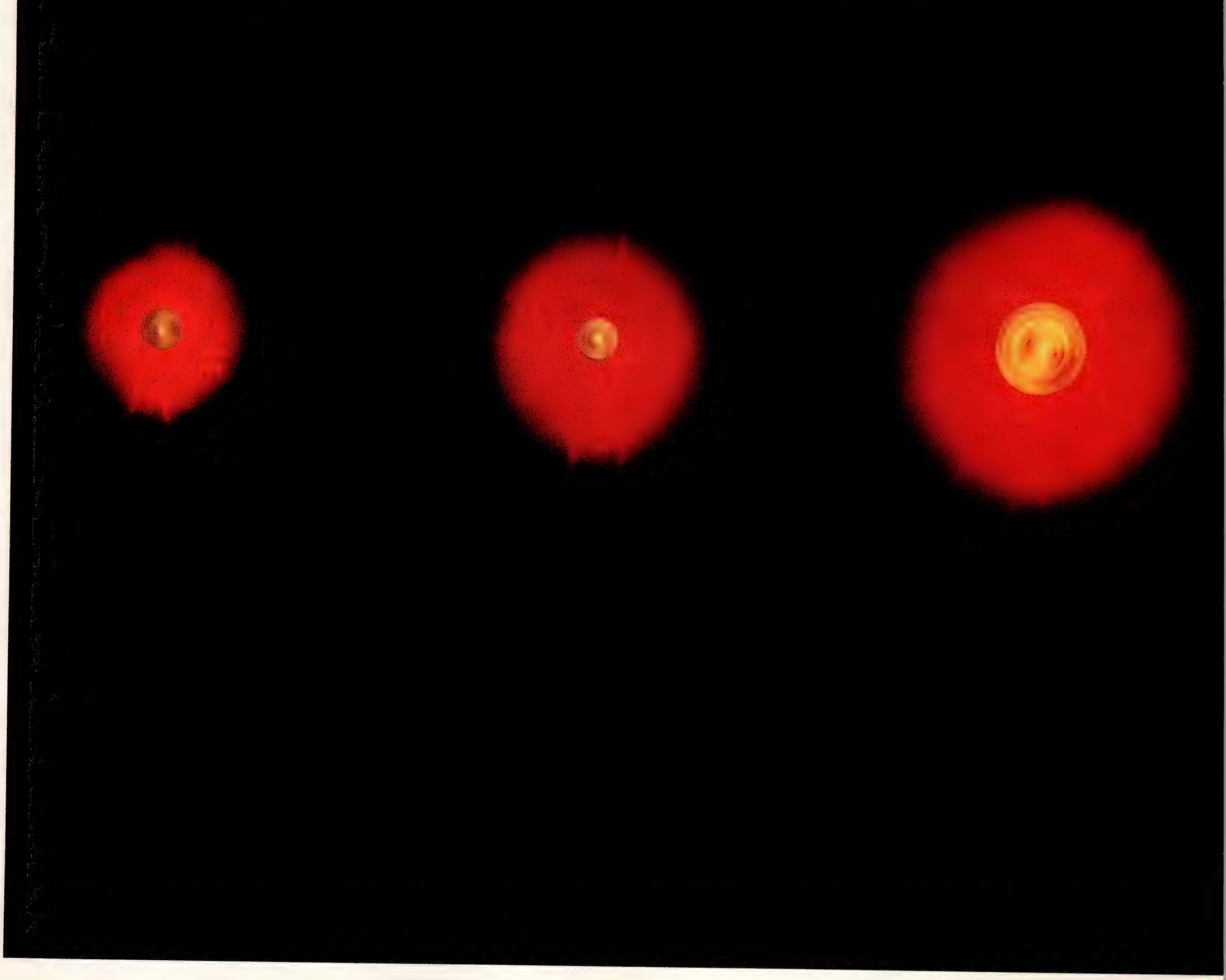
Mail to: Hewlett-Packard, HP 48SX Facts Kit, c/o Direct Mail Projects, P.O. Box 10598, Portland, OR 97210-9879
Offer good while supplies last.

EDN051090

221G

Simulated screens ©1990 Hewlett-Packard Company PG12002

Introducing Bright, Brighter and Brightest.



When it comes to high-intensity LED performance, HP can make you shine. In fact, we've got the brightest new ideas in TS-AlGaAs technology.

Our new TS-AlGaAs lamps combine HP's proven high-flux TS-AlGaAs technology with an advanced optical design to deliver unsurpassed LED performance.

What's more, HP is the only U.S. company who can provide you with the broad range of LED technology you need for all your high-intensity applications. And the only company anywhere who can deliver the world's brightest LED performance.

You can choose the HLMP-8103 or HLMP-8104. Both are standard-size TS-AlGaAs lamps, designed to provide very high intensity. The HLMP-8103, our 3 cd lamp, has a maximum intensity of 5.8 candelas. For an even brighter lamp, the HLMP-8104, our 4 cd lamp, delivers a maximum intensity of 8.4 candelas.

The HLMP-8150 TS-AlGaAs lamp has a maximum intensity of 25 candelas. Which makes it the brightest LED lamp in the world.

If your application calls for a high-intensity lamp with a wider viewing angle, HP's HLMP-8100 provides an angle of 24 degrees.

All of which makes HP's new TS-AlGaAs lamps the perfect choice for exterior moving message signs, exterior automotive lighting, incandescent replacement and sensors.

Best of all, they're from HP. So you're always assured of HP's commitment to excellence in service, support and reliability.

Fax inquiries to HP GmbH, Components Marketing Europe. **FAX (49) 7031-14-2216.** The brightest new ideas in LED performance.

There is a better way.

HEWLETT
PACKARD

CG08002

NEWS BREAKS

EDITED BY JULIE ANNE SCHOFIELD

SMALL MODULE LETS YOU PUT A VAX ON A PC BOARD

The rtVAV 300 circuit module from Digital Equipment Corp (Maynard, MA, (800) 344-4825) measures 3.1×4.6×0.54 in. You mount it on a pc board in your embedded real-time system. Once you've added memory and, possibly, peripheral control circuits, you've endowed your system with computing power roughly 2.7 times that of a VAX 11/780. A CPU, RAM cache, math coprocessor, and intelligent communications controller are surface mounted within the $2000 (including runtime license) module. The controller supports thin- and thick-wire Ethernet and TCP/IP (transmission control protocol/internet protocol) communication. The module dissipates 5W in normal operation and runs under the VAXELN operating-system kernel. After developing your application on a VAX running under the vendor's VMS operating system, you can place the VAXELN kernel and your application program in ROM or download them to the module's local RAM at boot time.—Dan Strassberg

LOW-COST PROCESSORS ADAPT SPARC FOR EMBEDDED CONTROL

SPARC processors are moving from workstations to embedded-control applications courtesy of LSI Logic (Milpitas, CA, (408) 433-8000) and the Ross Technology subsidiary of Cypress Semiconductor (San Jose, CA, (408) 943-2600). Both companies have introduced reduced-pin-count versions of the SPARC integer microprocessor at less than 25% of that processor's cost.

A full-featured SPARC processor offers a 32-bit address bus, 8 bits of address-space identifier, a floating-point coprocessor port, and a user-defined coprocessor port, all in a 208-pin pin-grid array. To create the CY7C611 lower-cost version, Ross Technology eliminated the user-defined coprocessor port and several control signals. The company also reduced the address bus to 24 bits and the address-space identifier to 3 bits. LSI Logic kept the full 32-bit address bus in its L64901 lower-cost SPARC processor, choosing instead to eliminate both coprocessor ports. Users of the L64901 who require floating-point math must perform their calculations entirely in software.

The reduced-SPARC processors come in 160-pin plastic quad flatpacks and operate at 25 MHz. Both retain complete binary compatibility with other SPARC processors. The CY7C611 costs $76 (1000) and will be in volume production by the third quarter; samples are available now. The L64901 costs $49 (10,000).—Richard Quinnell

SYNTHESIZE HIGH-FAULT-COVERAGE TEST PROGRAM

By showing your net list and behavioral-circuit description to the Test Design Expert, you can get test patterns that have high fault coverage. This fault coverage is independent of your design-for-test strategy. The Test Design Expert is a CAE software package from start-up ExperTest (Mountain View, CA, (415) 969-0701). The software runs on SPARCstations and accepts net lists in many common formats. The behavioral description should be in VHDL-T (VHSIC Hardware Description Language), a register-transfer-level subset of the IEEE VHDL-1076 specification. If your circuit uses full scan or is strictly combinational, the software doesn't need the behavioral description. The software produces test vectors and a fault report that you can use to back-annotate your circuit. It will be available in the fourth quarter for $150,000.—Michael C Markowitz

NEWS BREAKS

RASTER-OP ALU MANIPULATES FOUR BIT PLANES AT ONCE

By fabricating the functional equivalent of four raster-operation ALUs on one chip, VLSI Technology Inc (Tempe, AZ, (602) 752-6366) created a graphics device that can simultaneously manipulate four image planes. The VL82C164 IC can perform 256 raster operations on three operands: the image's source-memory location, the destination-memory location, and pattern data. Fall-through time on the device is 80 nsec. Samples of the VL82C164 are available now; the company expects to reach volume production in the third quarter. Volume pricing is $40 (1000).
—Steven H Leibson

CAE VENDOR ORCHESTRATES PACKAGE FOR SYSTEM DESIGN

The Amadeus System Design Series from Cadence Design Systems Inc (San Jose, CA, (408) 943-1234) comprises the Amadeus Composer text and graphics design-entry system; the Amadeus Analyzer entry-and-verification system; and the Verilog simulation, Veritime timing-analysis, and Verifault fault-grading software. Because of the software's harmony with the Verilog HDL, you can compose your design at the system level and refine it from the top down. The Synopsys (Mountain View, CA, (415) 962-5000) logic-synthesis tool, the Frame Technology (San Jose, CA, (408) 433-3311) publication and documentation tool, and Genrad's (Concord, MA, (508) 369-4400) Hilo are available as options in the Amadeus chorus. Cost of the Amadeus software ranges from $12,500 to $60,000, depending on hardware and software configurations.—Michael C Markowitz

SO LONG, ASIC VERIFIER; HELLO, ASIC TESTER

Integrated Measurement Systems, a subsidiary of Valid Logic Systems (Beaverton, OR, (503) 644-6969) has introduced a family of ASIC test stations for small production runs. The initial family member is the Logic Master XL 100+, which at $275,000 to $300,000 for a 128-pin system costs the same as its Logic Master XL ASIC-verifier predecessor. This price is about 15% that of testers optimized for throughput, but the tester doesn't test devices as quickly as more expensive ATE. Among the system's features are hybrid pin-electronics modules that use GaAs devices, a 385M-byte SCSI hard drive that loads test patterns, and an Ethernet interface that transfers data from workstations.—Dan Strassberg

MILITARY PROCESSORS TAKE THE RISC

Full military temperature range, 16-MHz versions of the LR3000 Mips Computer (Sunnyvale, CA, (408) 991-0221) RISC architecture microprocessor are available now from LSI Logic (Milpitas, CA, (408) 433-8000). The LR3000GX-16 CPU costs $187; the LR3010GX-16 floating-point accelerator costs $227 (100). The company is qualifying the same two parts to MIL-STD-883C. You can obtain the 883C devices in either ceramic leaded chip carriers or ceramic pin-grid arrays in the third quarter of this year.—Michael C Markowitz

MIDRANGE DEVICE PROGRAMMER TAKES AN UNUSUAL FORM

Data I/O Corp (Redmond, WA, (206) 881-6444) has announced the successor to its ubiquitous 29B midrange programmer. The 2900 programmer, which is approximately 12 in. in diameter and 3 in. high, handles memory and logic devices with as many as 44 pins. In the center of its circular top is a field of button contacts on

We build to suit.

How in heaven do you construct a microminiature connector capable of meeting the unearthly demands of a space suit?

ITT Cannon starts with a solid foundation of design expertise and the largest, most experienced design-engineering staff in the industry.

Upon that foundation we build customized microminiature design solutions. Just as we have for the space shuttles, 747s, supercomputers, pacemakers and scores of other projects.

In the process we've also built a strong reputation for creating microminiature technology that performs reliably in the most critical applications, under the most demanding conditions, at the most competitive prices.

And we're creating the future today. Micro products with contact spacing as small as .025 centers. Or flexible circuits terminated directly to the contacts. And even zero insertion force, surface mount and zipper connectors.

When you consider our strengths, there's only one choice to suit your connector needs. ITT Cannon.

For application assistance or to request our new brochure, call us at (714) 557-4700 today. Or write ITT Cannon, 666 E. Dyer Rd., P.O. Box 929, Santa Ana, CA 92702-0929 FAX: (714) 754-2142.

CIRCLE NO. 50

ITT Cannon
AN ITT EMC WORLDWIDE COMPANY
Discover our strengths.

which you place matchbook-like sockets that accommodate surface-mount devices and ICs in leaded packages. Gone are the cascaded adapters earlier programmers needed to accommodate some devices. Gone, too, is the lead inductance that caused reliability problems in such kludgey setups. A 3½-in. floppy-disk drive near the programmer's front accepts disks that contain libraries of programming algorithms. At the rear is an RS-232C port that, with the supplied software, can download programming data at 115.2k bps from the RS-232C port of any IBM PC-compatible computer having a 16-bit data bus. Another RS-232C port communicates with the PC or ASCII terminal you must supply to display the menu-driven user interface. Prices start at $3750.—Dan Strassberg

SINGLE-CHIP U TRANSCEIVER MEETS ISDN SPEC

The MC145472 U transceiver from Motorola (Austin, TX, (512) 928-6880) provides a link between an ISDN (Integrated Services Digital Network) central-office equipment network and customer equipment. The single-chip IC meets the ANSI 2B1Q U-technology specification (T1.601-1988). It includes three DSP devices and a 14-bit sigma-delta A/D converter and comes in a 68-pin ceramic quad flatpack. The $70 chip offers 144k-bps full-duplex transmission over a single twisted-pair loop. Production quantities won't be available until the fourth quarter, but you can purchase an evaluation kit for $900 now.—J D Mosley

SEA OF GATES DOESN'T CAST TESTABILITY ADRIFT

Oki Semiconductor's (Sunnyvale, CA, (800) 654-6994) MSM10T ASIC family is a 1-micron drawn, 0.85-micron L_{eff} family that offers 2376 to 40,608 usable gates. The arrays use an architecture that provides a sea of gates and also endows the array with preliminary scan-testable latch and flip-flop locations. The ratio of gates to registers is 704:16. According to the vendor, allowing for the registers on the uncommitted silicon permits optimization of the register cells. Optimized register cells statistically cost you no additional circuit area. A 2-input NAND gate with 2 mm of interconnect and a fan-out of 2 switches in 890 psec. Prices start at $5.08 (10,000) for the smallest array in a 44-pin plastic leaded chip carrier. Development charges for this array are $17,700 for 10 prototypes from a net list built from the vendor's library.—Michael C Markowitz

VHDL SIMULATOR BOOSTS SPEED

Release 2.0 of Zycad Corp's (Menlo Park, CA, (415) 688-7400) System VHDL (VHSIC Hardware Description Language) simulator features an 8-fold speed increase compared with the earlier version. The vendor benchmarked the software on a Sun 3/60 workstation using a linear-feedback shift register implemented at the gate level. The simulation time was 91 seconds, compared with 720 seconds for the earlier release. The software lets you change the delay values generated by software layout packages before and after you route your circuit. You can also override the simulator and assign a new value to any simulation structure. A code-execution report documents the number of times each line of a VHDL model executes. The software runs on computers and workstations from Sun Microsystems, Hewlett-Packard/Apollo, and Digital Equipment Corp. Production shipments will begin in June. The license fee starts at $40,000; existing System VHDL customers will receive Release 2.0 free of charge.—Julie Anne Schofield

Then call Dale.®

Imagine the exact circuit you need. Then call Dale® and get dozens of ways to package resistors, capacitors and other components. Reliably. Faster. And in less space.

We're ready to deliver all types of general purpose R/C networks in molded DIP and conformal-coated SIP styles for ECL, line and Thevenin equivalent termination. In addition, we're an established producer of custom circuits which combine a variety of active and passive components in DIP, SIP or special packages.

Need extra precision? Our laser trimming methods can achieve Resistor/Capacitor time constant matching of ±1%. Special testing? Our capabilities include temperature cycling from −55°C to +125°C and power conditioning at room temperature, 70°C and 125°C.

Imagine how Dale networks can help you do a better job. Then call (915) 592-3253 for immediate assistance or write: Dale Electronics, Inc., Box 26728, El Paso, TX 79926-6728.

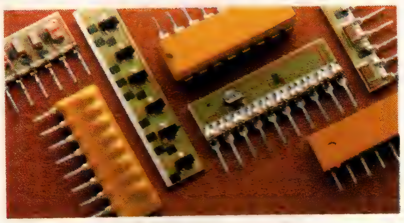
Remember, when it comes to delivering the networks you need — Dale Can.

DALE®

Dale Makes Your Basics Better

DALE ELECTRONICS, INC.
. . . a VISHAY Company

CIRCLE NO. 51



RF TRANS

Over 50 off-the-shelf models...

Having difficulty locating RF or pulse transformers with low droop, fast risetime or a particular impedance ratio over a specific frequency range?...Mini-Circuits offers a solution.

Choose impedance ratios from 1:1 to 36:1, connector or pin versions (plastic or metal case built to meet MIL-T-21038 and MIL-T-55831 requirements*). Ultra-wideband response achieves low droop and fast risetime for pulse applications. Ratings up to 1000M ohms insulation resistance and up to 1000V dielectric voltage. For wide dynamic range applications involving up to 100 mA DC primary current, use the T-H series. Coaxial connector models are offered with 50 and 75 ohm impedance; BNC standard; request other types. Available for immediate delivery with one-year guarantee.

Call or write for 68-page catalog or see our catalog in EEM, or Microwaves Product Data Directory.

*units are not QPL listed

case styles
T, TH, case W 38, X 65 bent lead version, KK81 bent lead version
TMO, case A 11, † case B 13 FT, FTB, case H 16
NEW TC SURFACE MOUNT MODELS from 1MHz to 1500 MHz

NSN GUIDE

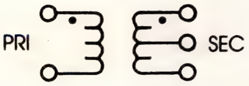
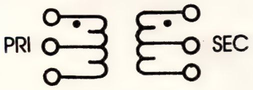
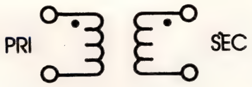
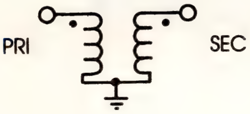
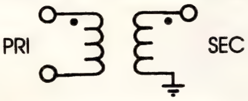
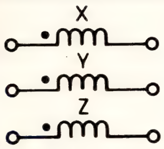
MCL NO.	NSN	MCL NO.	NSN
FTB1-1-75	5950-01-132-8034	TMO2-1	5950-01-183-6414
FTB1-6	5950-01-225-8773	TMO2.5-6	5950-01-215-4038
T1-1	5950-10-128-3745	TMO2.5-6T	5950-01-215-8697
T1-1T	5950-01-153-0668	TMO3-1T	5950-01-168-7512
T2-1	5950-01-106-1218	TMO4-1	5950-01-067-1012
T3-1T	5950-01-153-0298	TMO4-2	5950-01-091-3553
T4-1	5950-01-024-7626	TMO4-6	5950-01-132-8102
T9-1	5950-01-105-8153	TMO5-1T	5950-01-183-0779
T16-1	5950-01-094-7439	TMO9-1	5950-01-141-0174
TMO1-1	5950-01-178-2612	TMO16-1	5950-01-138-4593

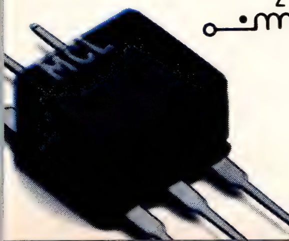
finding new ways ...
setting higher standards

Mini-Circuits
A Division of Scientific Components Corporation
P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500
Fax (718) 332-4661 Domestic and International Telexes: 6852844 or 620156

FORMERS

3KHz-800MHz from $\$3^{25}$

case style number see opposite page		MODEL NO.	Ω RATIO	FREQUENCY MHz	INSERTION LOSS			PRICE $
					3dB MHz	2dB MHz	1dB MHz	Qty. (1-9)
A* 	T	T1-1T	1	.05-200	.05-200	.08-150	.2-80	4.45
		T1-6T	1	.003-300	.003-300	.01-150	.02-50	6.95
		T2-1T	2	.07-200	.07-200	.1-100	.5-50	4.95
		T2.5-6T	2.5	.01-100	.01-100	.02-50	.50-20	4.95
		T3-1T	3	.05-250	.05-200	.1-200	.5-70	4.95
		T4-1	4	.2-350	.2-350	.35-300	2-100	3.25
		T4-6T	4	.02-250	.02-250	.05-150	0.1-100	4.45
		T5-1T	5	.3-300	.3-300	.6-200	.5-100	4.95
		T8-1T	8	.03-140	.03-140	.10-90	1-60	7.95
		T13-1T	13	.3-120	.3-120	.7-80	5-20	4.95
		T16-6T	16	.03-75	.03-75	.06-30	.1-20	5.65
	TH	T4-1H	4	10-350	10-350	15-300	25-200	5.95
	TMO	TMO1-1T	1	05-200	.05-200	.08-150	.2-80	7.95
		TMO2-1T	2	.07-200	.07-200	.1-100	.5-50	8.45
		†TMO2.5-6T	2.5	.01-100	.01-100	.02-50	.05-20	8.45
		†TMO3-1T	3	.05-250	.05-250	.1-200	.5-70	7.95
		TMO4-1	4	.2-350	.2-350	.35-300	2-100	6.25
		TMO5-1T	5	.3-300	.3-300	.6-200	5-100	8.45
		TMO13-1T	13	.3-120	.3-120	.7-80	5-20	8.45
B* 	TT	TT1-6	1	.004-500	.004-500	.02-200	.1-50	6.95
		TT1.5-1	1.5	.075-500	.075-500	.2-100	1-50	5.95
		TT2.5-6	2.5	.01-50	.01-50	.025-25	.05-10	6.45
		TT4-1	3	.05-200	.2-50	.2-50	1-30	5.95
		TT4-1A	4	0.1-300	0.1-300	0.2-250	0.3-180	6.95
		TT25-1	25	.02-30	.02-30	.05-20	.1-10	9.95
	TTMO	TTMO25-1	25	.02-30	.02-30	.05-20	.1-10	11.95
		TTMO1-1	1	.005-100	.005-100	.01-75	.05-40	11.45
		TTMO4-1A	4	0.1-300	0.1-300	0.2-250	0.3-180	13.95
C 	T	T1-1	1	.15-400	.15-400	.35-200	2-50	3.25
		T1.18-3	1.18	0.01-250	0.01-250	0.02-200	0.03-50	5.65
		T1-6	1	.01-150	.01-150	.02-100	.05-50	5.65
		T1.5-1	1.5	.1-300	.1-300	.2-150	.5-80	4.45
		T1.5-6	1.5	.02-100	.02-100	.05-50	0.1-25	5.65
		T2.5-6	2.5	.01-100	.01-100	.02-50	.05-20	4.45
		T4-6	4	.02-200	.02-200	.05-150	.1-100	4.45
		T9-1	9	.15-200	.15-200	.3-150	2-40	3.95
		T16-1	16	.3-120	.3-120	.7-80	5-20	4.45
		T36-1	36	.03-20	.03-20	.05-10	.1-5	6.95
	TO	TO-75	1	10-500	—	10-500	40-250	6.95
	TH	T1-1H	1	8-300	8-300	10-200	25-100	5.95
		T9-1H	9	2-90	2-90	3-75	6-50	6.45
		T16-H	16	7-85	7-85	10-65	15-40	6.45
	TMO	TMO1-02	1	1-800	1-800	2-500	—	9.45
		TMO1-1	1	.15-400	.15-400	.35-200	2-50	6.25
		TMO1.5-1	1.5	.1-300	.1-300	.2-150	.5-8	8.45
		†TMO2.5-6	2.5	.01-100	.01-100	.02-50	.05-20	7.95
		†TMO4-6	4	.02-200	.02-200	.05-150	.1-100	7.95
		TMO6-1	6	.3-200	.3-200	.5-150	5-50	7.95
		TMO9-1	9	.15-200	.15-200	.3-150	2-40	7.95
		TMO16-1	16	.3-120	.3-120	.7-80	5-20	7.95
D 	T	T2-1	2	.050-600	.050-600	.1-400	.5-200	3.95
		T3-1	3	.5-800	.5-800	2-400	—	4.45
		T4-2	4	.2-600	.2-600	.5-500	2-250	3.95
		T8-1	8	.15-250	.15-250	.25-200	2-100	3.95
		T14-1	14	.2-150	.2-150	.5-100	2-50	4.95
	TMO	TMO2-1	2	.050-600	.050-600	.1-400	.5-200	7.95
		TMO3-1	3	.5-800	.5-800	2-400	—	8.45
		TMO4-2	4	.2-600	.2-600	.5-500	2-250	7.95
		TMO8-1	8	.15-250	.15-250	.25-200	2-100	7.95
		TMO14-1	14	.2-150	.2-150	.5-100	2-50	8.45
	FT	FT1.22-1	1.22	.005-100	.005-100	.01-50	.05-25	35.95
		FT1.5-1	1.5	.1-400	.1-400	5-200	1-100	35.95
E 	FTB	FTB-1	1	.2-500	.2-500	.5-300	1-100	36.95
		FTB1-6	1	.01-125	.01-125	.05-50	.1-25	36.95
		■FTB-1-75	1	.5-500	.5-500	5-300	10-100	36.95
F 	T	T-622	1	0.1-200	0.1-200	0.5-100	5-80	3.25
		T626	1	0.01-10	0.01-10	0.2-5	.04-2	3.95



■ Denotes 75 ohm models

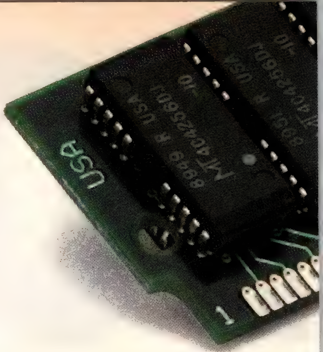
* FOR A AND B CONFIGURATIONS

Maximum Amplitude Unbalance
0.1 dB over 1 dB frequency range
0.5 dB over entire frequency range

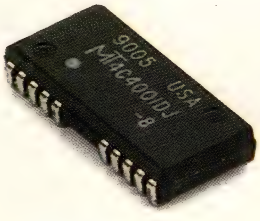
Maximum Phase Unbalance
1.0° over 1 dB frequency range
5.0° over entire frequency range

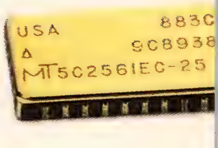
CIRCLE NO. 142

C72-2 REV. B



WE
APPROACH
THE MEMORY
BUSINESS
FROM ONE POINT
OF VIEW...





YOURS.

Component Product Family	Memory Size (Total)	Org. (Bits)	Speed (ns)	Package DIP	ZIP	SOJ	PLCC	SOG	PQFP	Special Features	Availability	Military Qualified
SRAMs	1MEG	x1,x4,x8	25-45	X		X				x4 option: OE	Samp: 1H90, Prod: 2H90	Samp: 2H90
	256K	x1,x4,x8	20-35	X	X	X				x4 option: OE	Now	X
	64K	x1,x4,x8	12-25	X		X				x4 options: Separate I/O, OE	Now	X
	16K	x1,x4,x8	12-25	X		X				x4 options: Separate I/O, OE	Now	X
Cache Data SRAMs	144K	x18	20-35				X		X	386/486 Compatible, Fast toe 8ns, Auto write completion, Parity bits	Samp: Now, Prod: 1H90	
	128K	x16	20-35				X		X	386 Compatible, Fast toe 8ns	Now	
SRAMs with Address Latch	16K	x8	100	X		X				Intel 8051 and 8096 compatible	Samp: Now, Prod: 1H90	X
	16K	x8	15-35	X		X				Compatible with high end micro controllers	Samp: Now, Prod: 1H90	X
FIFOs	36K	4Kx9	20-35	X			X			Family options: 300 mil DIP package, Programmable flags, Mailbox register, x16/18, 16 to 18	Samp: 2H90	
	18K	2Kx9	20-35	X			X				Samp: 2H90	
	9K	1Kx9	20-35	X			X				Samp: 2H90	
	4.5K	512x9	20-35	X			X				Samp: 2H90	
DRAMs	4MEG	x1,x4,x16	60-100	X	X	X		X		x4 option: Write per bit	x1,x4 Samp: 1H90, Prod: 2H90; x16: 1991	
	1MEG	x1,x4,x16	70-120	X	X	X	X	X		x16 options: Byte and/or masked write	x1, x4: Now; x16: 1H90	X
	256K	x1,x4	80-120	X	X	X	X				Now	X
	64K	x1	100-150	X			X				Now	X
Quad CAS DRAM	1MEG	x4	70-100			X				Separate CAS control for each DQ input/output	Samp: 1H90, Prod: 2H90	
Pseudo Static DRAM	1MEG	x8	80-120	X		X		X		Unmultiplexed addresses, Simple refresh control	Samp: 1H90, Prod: 2H90	
VRAMs	1MEG	x4,x8	80-120	X	X	X				CMOS, Fully static SAM, Block write, Split read transfer	Samp: 1H90, Prod: 2H90	Samp: 2H90
	256K	x4	100-150	X	X	X				CMOS, Fully static SAM, Serial input	Now	X

Module Product Family*	Word Size (Words)	Org. (Bits)	Speed (ns)	Package DIP	ZIP	SIP	SIMM			Special Features	Availability	Military Qualified
SRAM Modules	256K,64K,16K	x32	15-45		X					Industry standard pin-out with OE	16K, 64K: Now; 256K: 2H90	
	256K,64K,32K	x16	30-45	X						Industry standard pin-out with OE	32K, 64K: Now; 256K: 2H90	
	128K	x8	30-45	X						Compatible with 1MEG monolithic	Now	
DRAM Modules	2MEG,1MEG, 512K,256K	x36	70-120		X		X			Industry standard pin-out	256K, 512K: Now; 1MEG, 2MEG Samp: 2H90	
	4MEG,1MEG, 256K	x9	70-120			X	X			Industry standard pin-out	256K, 1MEG: Now; 4MEG Samp: 2H90	
	4MEG,1MEG, 256K	x8	70-120			X	X			Industry standard pin-out	256K, 1MEG: Now; 4MEG Samp: 2H90	
	256K	x5	100-120			X				Industry standard pin-out	Now	
	256K	x4	100-120			X				Industry standard pin-out	Now	

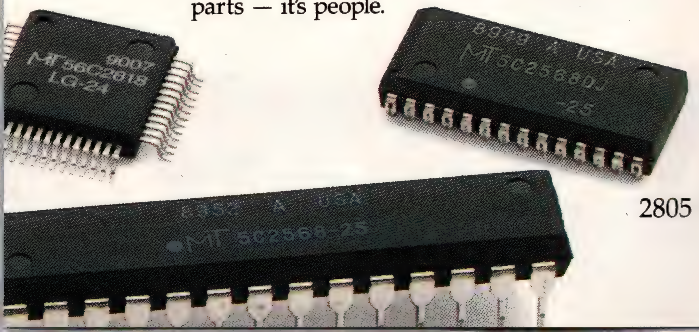
* Custom module and board-level product manufacturing services available.

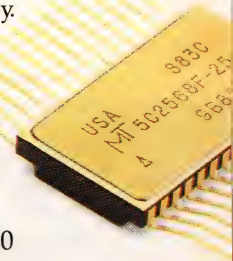
At Micron Technology, we offer a full line of leading-edge RAM components in speeds and packages for virtually any application.

But the memory business is more than just parts — it's people.

That's why we offer a total commitment to service and support, and a team of engineers and technical support personnel that are the most experienced memory professionals in the industry.

Because in the memory business there's only one point of view that counts. Yours.





MICRON
TECHNOLOGY, INC.
2805 E. Columbia Rd., Boise, ID 83706 (208) 386-3900

CIRCLE NO. 52

Asia Series

You can do business in Japan without shelling out a fortune.

For many companies, the biggest barrier to new markets has been the cost of business trips. Restaurants can be expensive, and even the smallest accommodations may carry oversized bills. Yet those willing to be a little adventurous will find that traveling comfortably in Japan doesn't require packing a suitcase full of yen.

Hop on the bus.

A $20 bus ride from Narita Airport may not strike you as a bargain, but compared to a $150 taxi, it is. The buses marked "Airport Limousine" stop at all the major hotels in Tokyo.

Sleep cheap.

Business hotels are a fairly new phenomenon. Catering primarily to Japanese businessmen, they're clean, functional, and conveniently located. Although vending machines replace amenities like room service, at $40 to $50 a night these hotels are a sound investment. Two major chains are the Tokyu Inn (tel. 03/406-0109) and the Washington (tel. 03/434-5211).

Food for naught.

It should come as no surprise that you'll save money eating where the locals eat. Good and reasonably priced restaurants can be found in department stores and the basements of office buildings. At lunch, ask for *teishoku*. It means special of the day, and includes rice, miso soup, salad, meat or fish, and dessert—all for around five dollars. *Ramenya* and *sobaya* (noodle shops) are perfect places for a quick and tasty meal.

Northwest notes.

Since your time is money too, we make it as quick and easy as possible for you to get to Japan, by offering daily nonstops from the most U.S. cities. So you can count on arriving when you want, rested and ready to do business. And we give you something else no other U.S. airline can: the knowledge, understanding and insight that comes from over 40 years of helping people do business in Asia. For international reservations, call your travel agent or Northwest at 1-800-447-4747. To find out more about doing business in Asia, call 1-800-553-2215, ext. 183.

© 1990 Northwest Airlines, Inc.

NORTHWEST AIRLINES

SIGNALS & NOISE

Comments on Macintosh-based CAE article

I found Michael Markowitz's Special Report on Macintosh-based CAE (EDN, March 1, 1990, pg 138) interesting, not so much for its statistics and conclusions as for the explanations offered by Michael to justify those statistics and conclusions.

He claims that "Having few choices means that you could be stuck if you're designing a circuit that exceeds the capacity..." Actually, it means no such thing. You could be more stuck with a thousand choices for poor software than if you had no alternatives at all, provided the one software package available is very good.

Michael identifies several software vendors who hold off porting their software to the Mac because "the demand just isn't there." If the Mac is such a great machine, then it follows that the lack of demand is due to the software vendors' inability to create great software for it. No engineering manager is going to pass up a "great" Mac and CAE system for $10,000 in favor of a comparable workstation system for $150,000. Most of the good Mac software packages were created for a potential (not actual) market. Only mediocre software cannot afford the risk of opening up new markets.

But most interesting is the sidebar on "What is a workstation?" because it's based largely on wrong facts. MultiFinder works just fine in a virtual-memory environment—it's just not available from Apple. But then, neither is CAE software. MultiFinder does pretty well at multitasking also, even without virtual memory. I often have three or four different programs running concurrently with no less throughput than I have gotten on a VAX running Unix.

Tom Pittman
Spreckels, CA

We don't need more sensationalism

Jon Titus's editorial concerning EM fields (EDN, March 15, 1990, pg 49) is exactly the kind of sensationalism that we don't need. Perhaps there is a case to be made, but he doesn't make it. Further, I haven't seen anyone make a claim that leads me to believe there is a significant cause for concern.

What is my risk for myeloid leukemia if I am an amateur radio operator? Is it 2.6 in 100,000 instead of 1 in 100,000? Is this significant to me as an individual? [Does the risk come from] the EM fields produced by the transmitter, or the

IEEE COMPUTER SOCIETY DATC®
acm SIGDA®

For more information contact DAC at:

7490 Clubhouse Rd., Suite 102
Boulder, CO 80301
(303) 530-4333
FAX (303) 530-4334

27th dac

27th ACM/IEEE DESIGN AUTOMATION CONFERENCE ®

JUNE 24 - 28, 1990

THE WORLD'S PREMIER CAD/CAM CONFERENCE

BECOME A PARTICIPANT IN THE CAD/CAM EVENT OF THE YEAR!

Over 130 papers, tutorials and panels.

Six full day tutorials Thursday, June 28, 1990.

Over 125 vendors of CAD hardware and software exhibiting products.

Over 50 exhibitor technical presentations Sunday, June 24, 1990, many announcing new products.

Advance Registration ends May 25, 1990!

ORANGE COUNTY CONVENTION CENTER,
ORLANDO, FLORIDA

CIRCLE NO. 1

power supplies in the room? If so, what frequencies do the offenders have?

The occurrence of miscarriages suffered by women using waterbeds and electric blankets sounds unconvincing in terms of EM fields. The tap water in a waterbed is conductive, therefore any EM field produced by the heater would not reach the user. (Maybe waterbeds are a way to protect yourself from EM fields.) I would look for a link between sleeping temperature and miscarriage.

All I'm suggesting is to be rational about this. Before long, there will be the same hysteria first produced when radio was introduced to the public in the 1920s. There were all sorts of stories about people claiming everything from bad dreams to electric shocks from their bedsprings.

Timothy G Knauer
Burnsville, MN

Misspelling and omitted information

I would like to point out some errors in the article, "Simulators for high-speed board design spot trouble" (EDN, December 21, 1989, pg 152).

First, the correct spelling for the name of our company is Dazix, which is derived from Daisy/Cadnetix. Second, in the table of EDA (electronic design automation) vendors supporting transmission-line and crosstalk-analysis CAE tools for digital pc boards (pg 155), some information was omitted. In addition to the features checked off for the Dazix's boardscope transmission-line simulation package, a check mark should have appeared under linear-load model and under the three trace types: strip, microstrip, and buried strip.

We feel this information is critical to our customers. Thank you for featuring transmission-line simulation technology and including our company in your story.

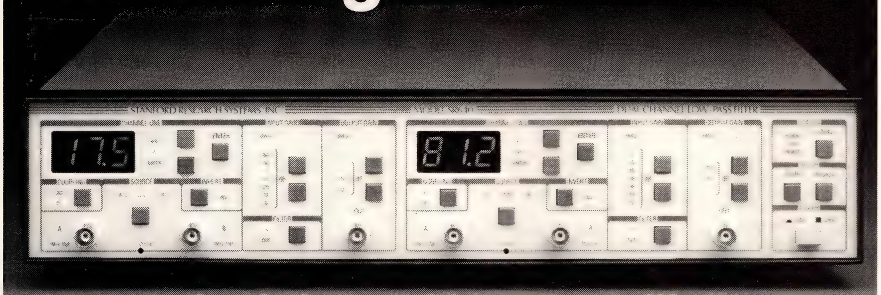
Mary Brown
Boardscope Product Mktg Mgr
Dazix
Mountain View, CA

Our apologies

Due to an editorial oversight, Performance Semiconductor Corp was left out of the Special Report on Static RAMs (EDN, February 15, 1990, pg 126). The company address and phone number are: 610 E Weddell Dr, Sunnyvale, CA 94089; (408) 734-9000. EDN regrets any confusion this may have caused.

EDN

Low and high pass filters for real signals



SR640 dual channel low-pass filter
SR645 dual channel high-pass filter
SR650 combination high/low-pass filter
Programmable, 115 dB/octave rolloff.
$2990.

The SR640, SR645 and SR650 offer unique combinations of filter specifications, preamplifier performance, and programmability at a price far less than other instruments. Featuring two fully independent 8-pole, 6-zero elliptic filters with less than 0.1 dB p-p passband ripple and 115 dB/octave rolloff, these filters are ideal for general purpose signal processing as well as anti-aliasing for digital signal processing systems.

The GPIB and RS232 interfaces allow complete control of all instrument settings via computer. The microprocessor components are optically isolated from the filter sections to provide optimum noise performance.

Whether your needs are for laboratory benchtop filters or signal conditioning filters in data acquisition systems, the SR640, SR645 and SR650 are the natural choices.

SR640, SR645, SR650

1 Hz to 100 kHz cutoff frequency
3 digit frequency resolution
0.1 dB passband ripple
115 dB/octave rolloff
80 dB stopband attenuation
4 nV/√Hz input noise
±0.5° phase match at f_c
60 dB prefilter gain
20 dB postfilter gain
GPIB, RS232 interfaces standard

SRS
Stanford Research Systems
1290 D Reamwood Avenue, Sunnyvale, CA 94089
TEL (408) 744-9040 FAX 4087449049
TLX 706891 SRS UD

CIRCLE NO. 2

Reduce Your Risc

New PACEMIPS™ Components - Less Space, Lower Cost

Now design your single-board RISC computer with three NEW Performance components: CPU/FPA R3400, PACEWRAP™, and BiCameral SCRAM™.

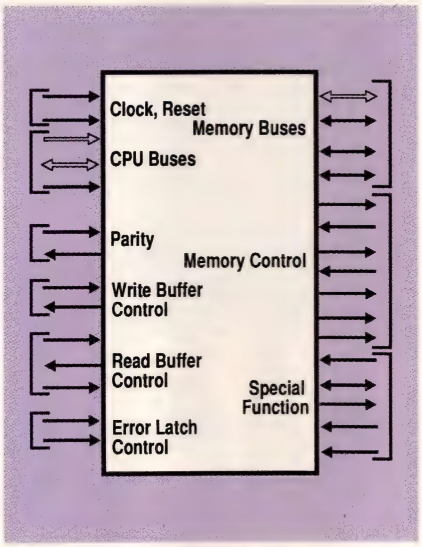
PACEMIPS R3400

CPU/FPA in a CPU Socket

- ☐ 25/33 MHz Operation
- ☐ Only 1.2 Clock Cycles/Instruction
- ☐ Up to 28 Mips and 9.7 MFLOPS
- ☐ 172 Lead Flat Pack/144 Pin PGA
- ☐ Full R3000/R3010 Functionality

PACEWRAP R3100

- ☐ Replaces four R3020s and up to 24 other chips.
- ☐ Eight-word-deep Write Buffer - with readback.
- ☐ Programmable Read Buffer - to 32 words and matches refill.
- ☐ Parity generation - allows use of main memory without parity.
- ☐ Bus snooping support.



PACEWRAP R3100 Block Diagram

BiCameral SCRAM Cache ZIP Module

- ☐ Dual 8Kx60 High-Speed SCRAM
- ☐ 32K Byte I and D caches from a single module including address latches.
- ☐ Available for up to 33 MHz CPU with minimum board space required.
- ☐ Space saving 6.0 x 0.815-inch 114-pin ZIP module

16Kx60 Cache SCRAM ZIP Module

- ☐ Two modules implement 64K Byte I & D caches including address latches.
- ☐ Available for up to 33 MHz CPU with minimum board space required.

For information or to order write or call . . .

Performance Semiconductor Corporation
610 E. Weddell Drive, Sunnyvale, California 94089
Telephone: (408) 734-9000

PERFORMANCE
SEMICONDUCTOR CORPORATION

PACE Technology is a trademark of Performance Semiconductor Corporation.
PACEMIPS is a joint trademark of Perfromance Semiconductor Corporation and MIPS Computer Systems, Inc.
PACEWRAP and BiCameral SCRAM are trademarks of Performance Semiconductor Corporation , Inc.

CIRCLE NO. 53

C&C Computers and Communications

For fast answers, call us at:

USA Tel:1-800-632-3531. TWX:910-379-6985. W. Germany Tel:0211-650302. Telex:8589960. The Netherlands Tel:040-445-845. Telex:51923. Sweden Tel:08-753-6020. Telex:13839. France Tel:1-3946-9617. Telex:699499. Italy Tel:02-6709108. Telex:315355. UK Tel:0908-691133. Telex:826791. Hong Kong Tel:755-9008. Telex:54561. Taiwan Tel:02-719-2377. Telex:22372. Korea Tel:02-551-0450. Fax:02-551-0451. Singapore Tel:4819881. Telex:39726. Australia Tel:03-267-6355. Telex:38343.

Now there's a smarter way to get a single-channel SCC.

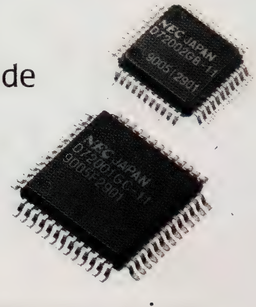
Cut a better deal with NEC's single-channel serial controller.

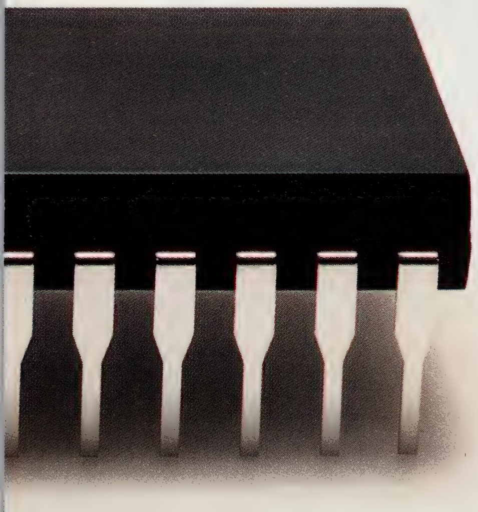
Successful engineers cut waste to create efficient designs. And we think it's pretty wasteful to buy a dual-channel serial communications controller when your system only uses one channel. That's why NEC developed the μPD72002, a single-channel version of our 72001 multi-protocol serial controller.

For single-channel data communications, our 72002 is the cost-efficient choice.

If you need two channels, our 72001 is a proven performer. Both devices offer advanced features, including:

☐ Functional superset of the 8530 SCC.
☐ SDLC/HDLC/SYNC/ASYNC protocol control.
☐ Two baud-rate generators per channel.
☐ A pair of transmit data-length registers per channel.
☐ Digital phase locked loop per channel.
☐ Speeds up to 2.5Mbps
☐ 12.5MHz system clock.
☐ CMOS with standby mode for reduced power consumption.
☐ DIP, PLCC and plastic quad flat packages.





Our 72001/002 lineup gives you unique flexibility in meeting both cost and performance goals. For more information, contact NEC today.

CIRCLE NO. 31

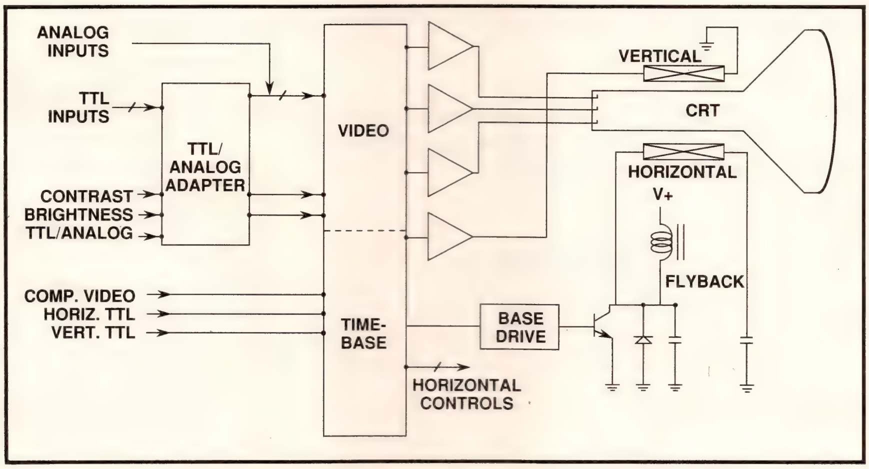
NEC

Make a splash in high resolution CRTs.

SCANSWITCH family of semiconductors, simple answers to horizontal deflection and video amplification problems.

For high resolution and ultra high resolution CRT applications, the SCANSWITCH™ family of semiconductors increase performance while reducing design complexity and cost.

The SCANSWITCH family consists of application specific horizontal output transistors, damper diodes and video amplifiers. They're all designed to improve performance in monochrome and color CRT monitors with horizontal scan frequencies of 50 kHz or greater. You get reduced power dissipation and the ability to work over the wide range that's required for multi-sync monitors.



For personal computer monitors, single-chip ICs are available to reduce design complexity and system cost.

Horizontal Output.

A new family of Switchmode III bipolar power transistors and companion damper diodes, ranging from 1,000 volts to 1,500 volts, have been specially designed for high and very high resolution horizontal deflection circuits. The transistors are optimized for dynamic desaturation, fall times and storage times. Their companion diodes are optimized for forward recovery times, avalanche energy and reverse recovery times. Together, they're the perfect solution.

Video Amplifiers.

The SCANSWITCH family includes two new high speed video amplifiers designed for ultra-high resolution graphics applications. These hybrid video amplifiers have a 130 MHz minimum bandwidth at 40V and 60V swings. Capacitive loads are driven directly or through transmission lines with no output tuning or need for critical external components. These amplifiers offer minimum power dissipation for all monochrome and color applications.

Multimode horizontal, vertical and video processor.

The SCANSWITCH multimode monitor chipset simplifies multimode monitor designs by reducing component count and design complexity in multimode monitors. This family of devices includes four integrated circuits, one exclusively for TTL-to-analog conversion, and three variations of timebase/video circuits. Only two of these ICs are required to design a complete multimode monitor system, replacing a large number of chips and discrete devices.

The set consists of two companion chips—a multimode monitor horizontal, vertical and video combination processor, and a multi-sync monitor TTL-to-analog inputs interface.

Let's not forget the switching power supply. Complete your monitor design with one of Motorola's broad line of state-of-the-art integrated circuits and discrete power semiconductors.

Get more information.

If you'd like more information on any of the devices in our SCANSWITCH family, contact your local Motorola sales office or complete and return the coupon below.

MOTOROLA INC.
European Semiconductor Group

Write To: Motorola Ltd., European Literature Centre, 88 Tanners Drive
Blakelands, Milton Keynes MK14-5BP, United Kingdom

Please send me more information about the SCANSWITCH family of semiconductors.

431EDN051090

Name ____________________

Title ____________________

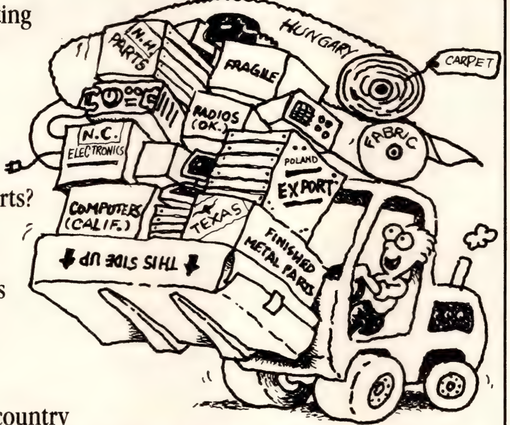
Company ____________________

Address ____________________

City ____________________

Country ____________________

Clear Out Your Excess Parts And Earn Tax Benefits Up To 200 %



Q: How can my company benefit by donating excess parts, assemblies and products?

A: Your donations could be good for an above cost tax deduction of up to 200 % under IRS 170(e)(3).*

Q: Who could possibly need my excess parts?

A: Over 700,000 students in community, technical and four-year colleges need thousands of metal, electric, electronic parts and all kinds of equipment for **training.**

Q: How do the colleges get them?

A: We have nine warehouses around the country where members (colleges and other non-profits) come in and select what they need.

Q: Is this a unique service?

A: Absolutely. No one else can match our **network** of warehouses. Fast service for over 900 companies and hundreds of colleges. We are the only **non-profit** 501(c)(3) offering this. So call or write today and we'll reply within 48 hours.

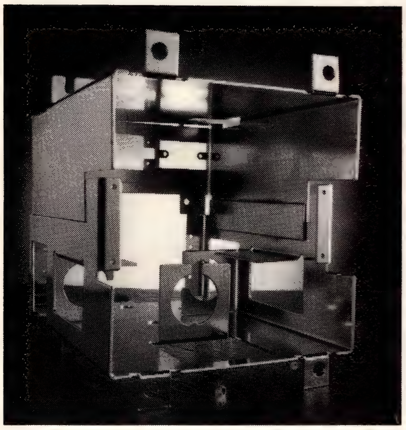
Company/College
Gifts-In-Kind Clearing House
P. O. Box 850 Davidson, NC 28036 704/892-7228

*Certain limitations apply.

Our expanded program includes Eastern bloc countries — Hungary, Poland, etc.

CIRCLE NO. 3

From simple to complex...

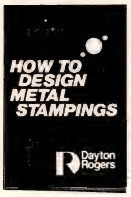


Stamping assemblies

Now you can outsource stamping assemblies including secondary operations such as custom fastener installation, spot welding, plating, painting and silk screening. Apply our 60 years of short run stamping experience for increased product reliability.

CAD in a high-tech environment, supported by EDI, can fulfill all your stamping assemblies needs, from 25 units and up. Call 612/871-2471 for information or FAX your print and specifications to: 612/871-2646.

Ask for FREE 36-page booklet



Dayton Rogers
MANUFACTURING CO
2824 - 13th Avenue So., Minneapolis, MN 55407

Minneapolis, MN • Rochester, NY • St. Petersburg, FL • Columbus, OH • Arlington, TX • Eugene, OR • Van Nuys, CA

CIRCLE NO. 4

CALENDAR

Custom Integrated Circuits Conference 1990, Boston, MA. Roberta Kaspar, Technical Program Coordinator, CICC, 1597 Ridge Rd W, Suite 101C, Rochester, NY 14615. (716) 865-7164. FAX (716) 865-2639. May 13 to 16.

Commercially Available Single-Board Computers and Real-Time Operating Systems (conference), Palo Alto, CA. DSP Associates, 18 Peregrine Rd, Newton, MA 02159. (617) 964-3817. FAX (617) 969-6689. May 14 to 17.

Midwest Electronics Exposition, St Paul, MN. MG Expositions Group, 1050 Commonwealth Ave, Boston, MA 02215. (800) 223-7126; in MA, (617) 232-3976. FAX (617) 232-0854. May 15 to 17.

Quality Week 1990, San Francisco, CA. Software Research Inc, 625 Third St, San Francisco, CA 94107. (800) 942-7638; in CA, (415) 957-1441. FAX (415) 957-0730. May 15 to 18.

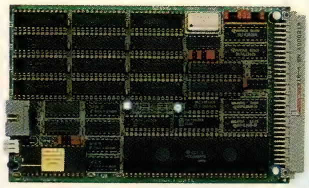
Hands-On UNIX for Programmers (short course), Seattle, WA. Specialized Systems Consultants Inc, Box 55549, Seattle, WA 98155. (206) 527-3385. FAX (206) 527-2806. May 16 to 18.

Designing for Electromagnetic Compatibility, Raleigh, NC. Hewlett-Packard Co, Signal Analysis Div, 1212 Valley House Dr, Rohnert Park, CA 94928. (404) 953-1840. May 21 to 22.

40th Electronic Components and Technology Conference, Las Vegas, NV. Jim Bruorton, c/o Kemet Electronics Corp, Box 5928, Greenville, SC 29606. (803) 963-6621. May 21 to 23.

Worst Case Circuit Analysis (short course), Chicago, IL. The Center for Professional Advancement, Box

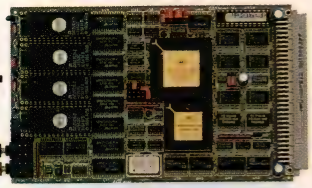
Who Said You Can't Have It All?



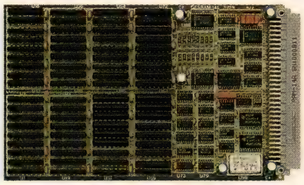
COLOR GRAPHICS
- 640x480x256 Colors • 800x600x256 Colors
- EGA • VGA* • Touch Screen EL Display

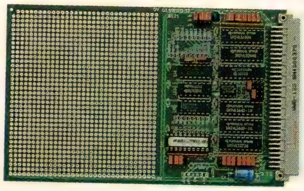
16 & 32-bit PROCESSORS

• Intel	• Motorola
8088	68000
80186	68010
80286	68020
80386SX*	68030

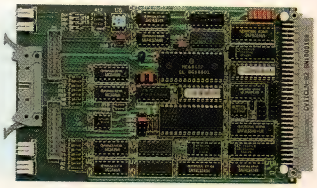


STATIC & DYNAMIC MEMORIES
- 512K to 8 Mbytes Dynamic Memory Boards
- Universal EPROM/RAM Static Memory Boards
- System Expandable to 32Mb

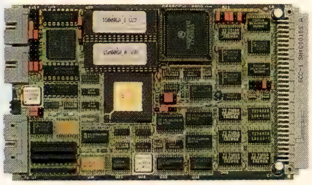




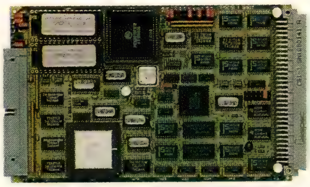
ACCESSORIES
- Predecoded Prototyping Boards
- Terminal Strip Adapters
- Power Supplies • Bus Extenders
- Packaging Products



VISION SUBSYSTEMS
- 256 to 2048 Elements Linear CCD Cameras
- Matrix CCD Cameras Interfaces
- Real-Time Image Processing Hardware

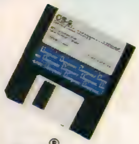


NETWORKING
- 10 Mb/s Ethernet® • 1 Mb/s Arcnet®
- 10 Mb/s X25 • 1 Mb/s IEEE 488
- 1 Mb/s GESNET® • 375 Kb/s Bitbus®

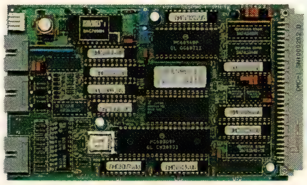


MASS STORAGE
- 3.5'' & 5.25'' Floppy Disk Controllers and Drives
- ST506 Winchester Controller and Drives (up to 70 Mb)
- Intelligent SCSI Controller (up to 1+ Gb)
- Tape Streamer

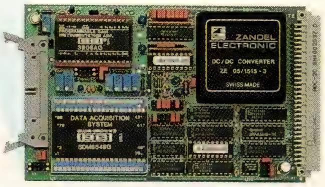
MS-DOS®
- Popular and User Friendly Single Task, Single User Operating System
- Runs on Intel Processor Based Systems
- Allows the Use of Any of Thousands of PC Software Products
- ROMed Version Available for Applications in Harsh Environment



OS-9®
- Real-Time Multitasking, Multi-User Operating System for Motorola Processors
- UNIX-like Syntax and UNIX® Compatible C Library
- Modular and Totally ROMable Software Architecture
- Editor, Assembler and C Compilers Allows Self Hosted Software Development
- Cross Development Tools Available for PC and UNIX Workstations



MOTION CONTROL
- DC Servo controllers
- Stepper Motor Controllers
- Shaft Encoder



INPUT/OUTPUT INTERFACES
- RS 232 / 442 / 485 SIOs
- Parallel TTL I/Os
- 10, 12 and 16-bit A/D & D/A
- Thermocouple, RTD, Resolver Interfaces
- Opto Isolated I/Os
- Mechanical & Solid State Relays

Whoever said that obviously doesn't know about GESPAC. With GESPAC, you get nearly 200 boards designed to **work together**, available from under a single roof and backed by a team dedicated to your success. What's more, all of these boards are supported with two operating systems (MS-DOS® and OS-9®) a choice of Real-Time kernels, a choice of IBM PC or UNIX® based cross development tools, and virtually one software driver for every board we make.

Call us today to receive the industry's most comprehensive catalog of microsystem solutions. See how GESPAC can help you build the system that best meet your unique specifications, in the shortest amount of time.

Call Toll Free 1-800-4-GESPAC or call (602) 962-5559.

Gespac

USA - CANADA
50 West Hoover Ave.
Mesa, Arizona
85210 USA
Tel. (602) 962-5559
Fax. (602) 962-5750

EUROPE
Z.I. des Playes
83500 La Seyne
France
Tel. 94 30 34 34
Fax. 94 87 35 52

INTERNATIONAL
18, Chemin des Aulx
CH-1228 Geneva
Switzerland
Tel. (022) 794 3400
Fax. (022) 794 6477

Record your thoughts no matter where you are with Lanier's microcassette Pocket Protege.

Lanier also has dictation units for your office. And the latest digital systems for companies of any size. All backed by the most experienced company in the business. Call Lanier. 1-800-241-1706.

Or send us your business card and this ad for more information on: ☐ Dictation
☐ Telephones
☐ Facsimile
☐ Copiers

Mail to: Lanier, P. O. Box 3064.
Cedar Rapids, Iowa 52406-9958. Or call
1-800-241-1706. Fax: 404-329-8369.

CIRCLE NO. 5

"MATHCAD IS THE BEST THING TO HAPPEN TO THE ENGINEER SINCE THE POCKET PROTECTOR."
— PC Magazine

For problems involving engineering calculations or scientific analysis, the answer is MathCAD®

MathCAD is the only PC-based software package specifically designed to give technical professionals the freedom to follow their own scientific intuition. You decide how to solve the problem – MathCAD does the "grunt work."

- Ends tedious programming and debugging.
- Displays instant answers as you change variables.
- Generates quick plots to help you view results.

MathCAD includes such built-in features as:

- Matrix operations
- Simultaneous equation solver
- Real and complex numbers
- Dynamic error flagging
- Automatic unit conversions
- Greek character set
- Fast Fourier Transform and much more

To find out what MathCAD can do for you, call us today for a **free demo disk: 1-800-MathCAD** (in MA, 617-577-1017). Or write to MathSoft, Inc., One Kendall Square, Cambridge, Massachusetts 02139.

Requires IBM® PC or compatible, 512KB RAM, graphics card.

Math Soft
Σ + √ − = × ∫ ÷ δ
Software Tools for Calculating Minds #13

CIRCLE NO. 6

CALENDAR

H, East Brunswick, NJ 08816. (201) 613-4535. FAX (201) 238-9113. May 21 to 23.

AeroMat '90—the Advanced Aerospace Materials/Processes Conference and Exposition, Long Beach, CA. ASM International, Materials Park, OH 44073. (216) 338-5151. FAX (216) 338-4634. May 21 to 24.

Data Base: A Builder's Guide, Atlanta, GA. Technology Transfer Institute, 741 Tenth St, Santa Monica, CA 90402. (213) 394-8305. FAX (213) 451-2104. May 21 to 25.

Modern Power Conversion Design Techniques, Boston, MA. Joy Bloom, Bloom Associates Inc, Educational Div, 115 Duran Dr, San Rafael, CA 94903. (415) 492-8443. FAX (415) 492-1239. May 21 to 25.

44th Annual Frequency Control Symposium, Baltimore, MD. Dr Raymond L Filler, US Army Electronics Technology and Devices Laboratory, Attn SLCET-EQ, Fort Monmouth, NJ 07703. (201) 544-2467. May 23 to 25.

Advances in Tape Automated Bonding, Sunnyvale, CA. Anthony Masessa, Semiconductor Technology Center, 1501 Cedar Crest Blvd, Suite 107, Allentown, PA 18104. (215) 435-0181. FAX (215) 799-2677. May 25.

Concurrent Engineering Seminar, Framingham, MA. Tina Nuss, Logical Solutions Technology Inc, 96 Shereen Pl, Suite 101, Campbell, CA 95008. (408) 374-3650. FAX (408) 374-3657. May 30 to 31.

Digital Multimedia: The New Technology Wave, Boston, MA. BIS CAP International, Research Publications and Conferences Div, Box 68, Newtonville, MA 02160. (617) 893-9130. FAX (617) 894-5093. May 30 to June 1.

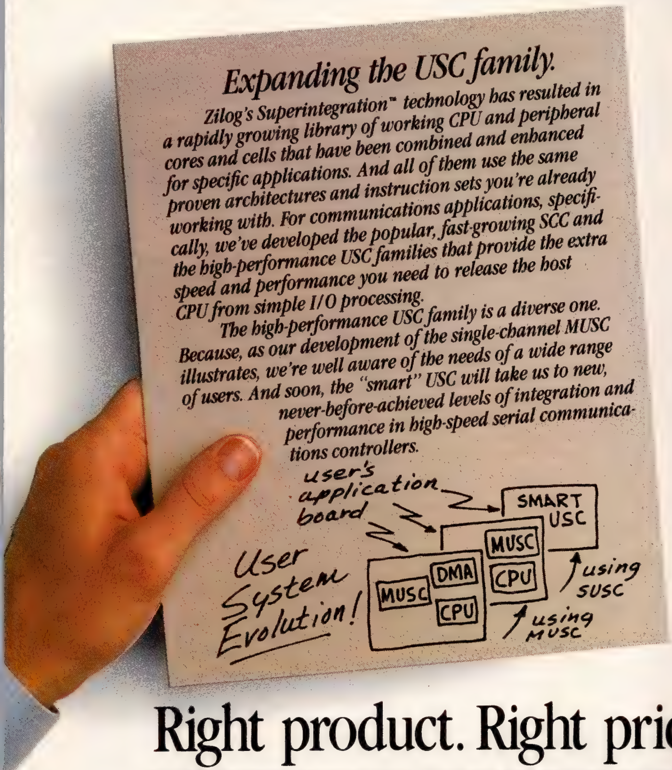
ZILOG

Now you can build 10 Mbit high-performance into your single-channel designs.

Zilog's MUSC, mono-channel universal serial communications controller (Z16C33™), has been designed specifically for high-performance applications that require only one high-speed channel. And it costs you about 40% less than the dual-channel USC.

All the performance you want.

The MUSC's 10 Mbit/sec data transfer rate makes it the fastest single-channel general purpose controller available. CMOS and Superintegration™ give you higher throughput, while helping reduce the CPU workload. And the 32-byte FIFO transmit-and-receive buffers help reduce CPU overhead. So does the fact that the MUSC integrates two time slot assignment cells—one for receive and one for transmit. So data is automatically inserted into programmed time slots, reducing CPU overhead and external logic even more. And all of that frees up more CPU power for the system. The final touch is a separate 8-bit parallel I/O port, ideal for status or displays, that adds flexibility in local control or data presentation.



Expanding the USC family.

Zilog's Superintegration™ technology has resulted in a rapidly growing library of working CPU and peripheral cores and cells that have been combined and enhanced for specific applications. And all of them use the same proven architectures and instruction sets you're already working with. For communications applications, specifically, we've developed the popular, fast-growing SCC and the high-performance USC families that provide the extra speed and performance you need to release the host CPU from simple I/O processing.

The high-performance USC family is a diverse one. Because, as our development of the single-channel MUSC illustrates, we're well aware of the needs of a wide range of users. And soon, the "smart" USC will take us to new, never-before-achieved levels of integration and performance in high-speed serial communications controllers.

All the flexibility you need.

The MUSC's multiprotocol design lets you adapt your system to a variety of networks. But not only do you get 10 protocols, you get 8 encoding formats—including asynchronous, bit and byte synchronous, isochronous, Ethernet, and MIL-STD 1553B. And the Open Systems Interconnect (OSI) model features Time Slot Assignment that allows transmission of time multiplexed Synchronous Data Link Control (SDLC) protocol to the ISDN link level.

All the reliability you've come to expect.

Of course, the MUSC comes to you off the shelf, with Zilog's proven quality and reliability. And you have the advantage of CMOS and Superintegration. But you also have the MUSC's unique built-in bus-oriented testability, which allows access to nodes and registers for testing program functionality in real time. And, since dedicated pointer registers provide a window to serial flow during on-line testing, you can test transmission reliability of the controller during system operation.

To find out more about the MUSC or any of Zilog's rapidly growing family of Superintegration products, contact your local Zilog sales office or your authorized distributor today. Zilog, Inc., 210 Hacienda Ave., Campbell, CA 95008, (408) 370-8000.

Right product. Right price. Right away.

ZiLOG

ZILOG SALES OFFICES: CA (408) 370-8120, (714) 838-7800, (818) 707-2160, **CO** (303) 494-2905, **FL** (813) 585-2533, **GA** (404) 448-9370, **IL** (312) 517-8080, **NH** (603) 888-8590, **MN** (612) 831-7611, **NJ** (201) 382-5700, **OH** (216) 447-1480, **PA** (215) 653-0230, **TX** (214) 987-9987, **WA** (206) 523-3591, **CANADA** Toronto (416) 673-0634, **UNITED KINGDOM** Maidenhead (44) (628) 39200, **W. GERMANY** Munich (49) (89) 672045, **JAPAN** Tokyo (81) (3) 587-0528, **HONG KONG** Kowloon (852) (3) 723-8979, **KOREA** (82) (2) 552-5401, **TAIWAN** (886) (2) 741-3125, **SINGAPORE** 65-235 7155, **DISTRIBUTORS: U.S.** Anthem Electronics, Hall-Mark Electronics, JAN Devices, Inc., Schweber Electronics, Vargas Electronics, Western Microtechnology, **CANADA** Future Electronics, SEMAD, **LATIN AMERICA** Argentina—Yel.-(1) 46-2211, Brazil—Digibyte (011) 581-1945, Semiconductores Profesionales (5) 536-1312.

CIRCLE NO. 54

FILTERS

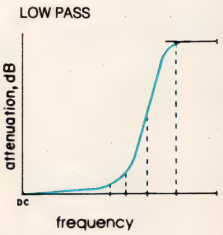
dc to 3GHz from $\$11^{45}$

lowpass, highpass, bandpass, narrowband IF

- less than 1dB insertion loss • greater than 40dB stopband rejection
- 5-section, 30dB/octave rolloff • VSWR less than 1.7 (typ) • meets MIL-STD-202 tests
- rugged hermetically-sealed pin models • BNC, Type N; SMA available
- surface-mount • over 100 off-the-shelf models • immediate delivery

low pass dc to 1200MHz

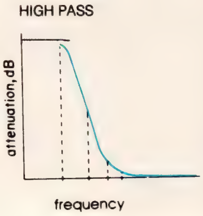
LOW PASS



MODEL NO.	PASSBAND, MHz (loss <1dB)	fco, MHz (loss 3db)	STOP BAND, MHz (loss>20dB)	(loss>40dB)		VSWR pass-band typ.	stop-band typ.	PRICE $ Qty. (1-9)
	Min.	Nom.	Max.	Max.	Min.			
PLP-10.7	DC-11	14	19	24	200	1.7	18	11.45
PLP-21.4	DC-22	24.5	32	41	200	1.7	18	11.45
PLP-30	DC-32	35	47	61	200	1.7	18	11.45
PLP-50	DC-48	55	70	90	200	1.7	18	11.45
PLP-70	DC-60	67	90	117	300	1.7	18	11.45
PLP-100	DC-98	108	146	189	400	1.7	18	11.45
PLP-150	DC-140	155	210	300	600	1.7	18	11.45
PLP-200	DC-190	210	290	390	800	1.7	18	11.45
PLP-250	DC-225	250	320	400	1200	1.7	18	11.45
PLP-300	DC-270	297	410	550	1200	1.7	18	11.45
PLP-450	DC-400	440	580	750	1800	1.7	18	11.45
PLP-550	DC-520	570	750	920	2000	1.7	18	11.45
PLP-600	DC-580	640	840	1120	2000	1.7	18	11.45
PLP-750	DC-700	770	1000	1300	2000	1.7	18	11.45
PLP-800	DC-720	800	1080	1400	2000	1.7	18	11.45
PLP-850	DC-780	850	1100	1400	2000	1.7	18	11.45
PLP-1000	DC-900	990	1340	1750	2000	1.7	18	11.45
PLP-1200	DC-1000	1200	1620	2100	2500	1.7	18	11.45

high pass dc to 2500MHz

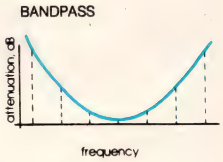
HIGH PASS



MODEL NO.	PASSBAND, MHz (loss <1dB)		fco, MHz (loss 3db)	STOP BAND, MHz (loss>20dB)	(loss>40dB)	VSWR pass-band typ.	stop-band typ.	PRICE $ Qty. (1-9)
	Min.	Min.	Nom.	Min.	Min.			
PHP-50	41	200	37	26	20	1.5	17	14.95
PHP-100	90	400	82	55	40	1.5	17	14.95
PHP-150	133	600	120	95	70	1.8	17	14.95
PHP-175	160	800	140	105	70	1.5	17	14.95
PHP-200	185	800	164	116	90	1.6	17	14.95
PHP-250	225	1200	205	150	100	1.3	17	14.95
PHP-300	290	1200	245	190	145	1.7	17	14.95
PHP-400	395	1600	360	290	210	1.7	17	14.95
PHP-500	500	1600	454	365	280	1.9	17	14.95
PHP-600	600	1600	545	440	350	2.0	17	14.95
PHP-700	700	1800	640	520	400	1.6	17	14.95
PHP-800	780	2000	710	570	445	2.1	17	14.95
PHP-900	910	2100	820	660	520	1.8	17	14.95
PHP-1000	1000	2200	900	720	550	1.9	17	14.95

bandpass 20 to 70MHz

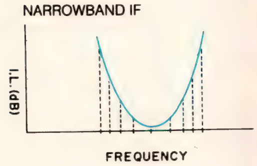
BANDPASS



MODEL NO.	CENTER FREQ. MHz F0	PASS BAND, MHz (loss <1dB) Max. F1	Min. F2	STOP BAND, MHz (loss > 10 dB) Min. F3	Max. F4	(loss > 20 dB) Min. F5	Max. F6	VSWR 1.3:1 typ. total band MHz	PRICE $ Qty. (1-9)
PIF-21.4	21.4	18	25	4.9	85	1.3	150	DC-220	14.95
PIF-30	30	25	35	7	120	1.9	210	DC-330	14.95
PIF-40	42	35	49	10	168	2.6	300	DC-400	14.95
PIF-50	50	41	58	11.5	200	3.1	350	DC-440	14.95
PIF-60	60	50	70	14	240	3.8	400	DC-500	14.95
PIF-70	70	58	82	16	280	4.4	490	DC-550	14.95

narrowband IF

NARROWBAND IF



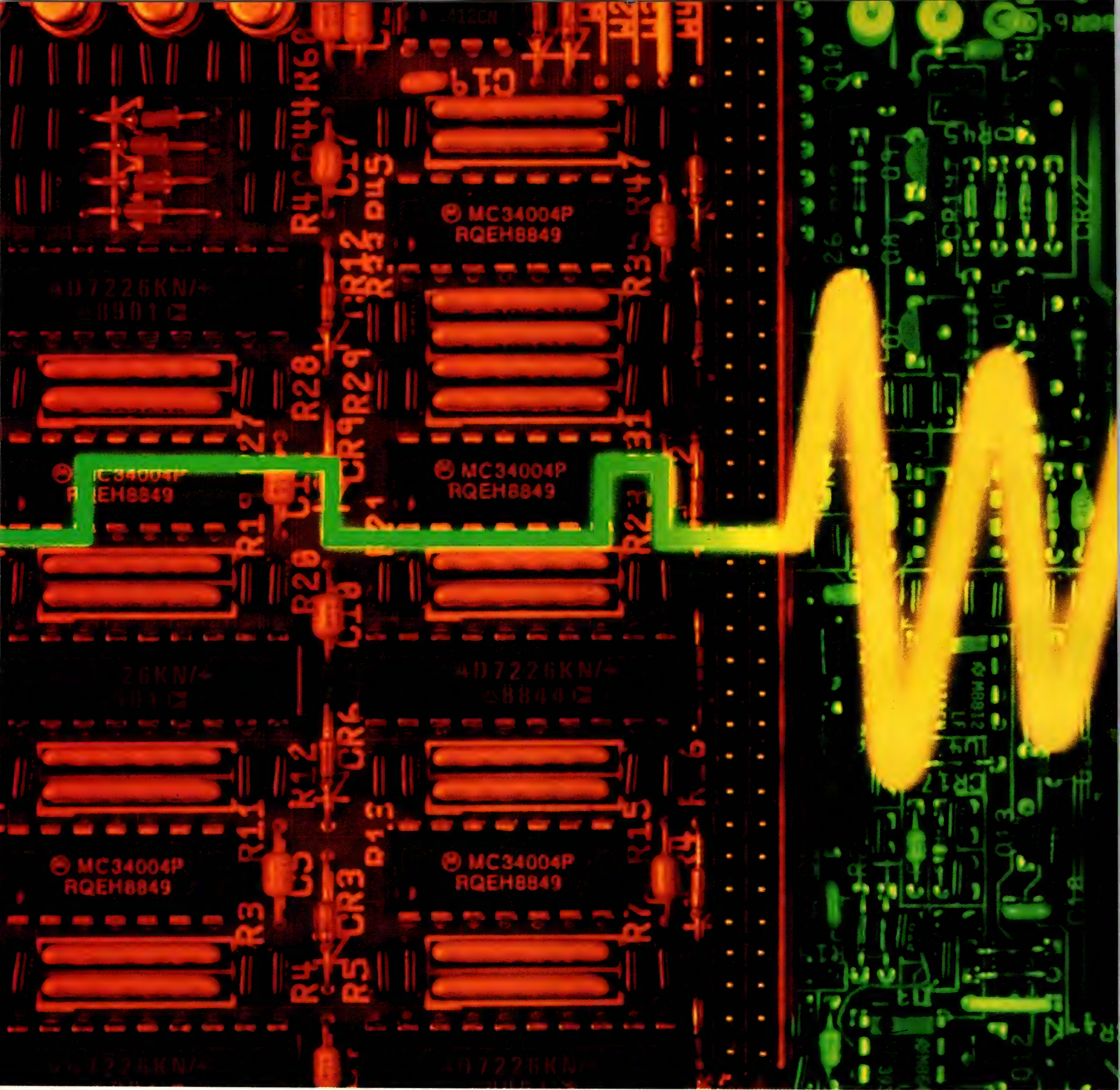
MODEL NO.	CENTER FREQ. MHz F0	PASS BAND, MHz I.L. 1.5dB max. F1-F2	STOP BAND, MHz I.L. > 20dB F5	F6	STOP BAND, MHz I.L. > 35dB F7	F8-F9	PASS-BAND VSWR Max.	PRICE $ Qty. (1-9)
PBP-10.7	10.7	9.5-11.5	7.5	15	0.6	50-1000	1.7	18.95
PBP-21.4	21.4	19.2-23.6	15.5	29	3.0	80-1000	1.7	18.95
PBP-30	30.0	27.0-33.0	22	40	3.2	99-1000	1.7	18.95
PBP-60	60.0	55.0-67.0	44	79	4.6	190-1000	1.7	18.95
PBP-70	70.0	63.0-77.0	51	94	6	193-1000	1.7	18.95

CIRCLE NO. 141

Mini-Circuits

P.O. BOX 350166, Brooklyn, New York 11235-0003 (718) 934-4500 FAX (718) 332-4661 TELEX 6852844 or 620156 **WE ACCEPT AMERICAN EXPRESS**

F132-2 REV. ORIG.



The smart choice in board testing

The L350 combinational board tester.

Now there's a combinational board tester that helps you test the most challenging VLSI technologies – from high-speed VLSI and ASICs to mixed signal and scan. The L350 has 20 MHz digital, SuperFast Analog,™ and automated boundary scan testing. And over 3,000 test pins.

What's more, you don't have to be a programming whiz to get great test results. The L350 has expert software that reviews PC board testability before you commit to artwork. Its advanced knowledge base generates accurate, repeatable in-circuit and cluster tests. And it analyzes test results, providing one clear repair message per fault.

is the smartest board tester.

The L350 gives you smart hardware too, with multiple dedicated processors for highest analog and digital throughput. Now, in thirty seconds or less, you can get 100% interconnect coverage, 100% device coverage, and 100% pin-level fault coverage on dense, complex boards. Just the answer for automated and JIT manufacturing.

Best of all, using the L350 with our BoardWatch® test quality management software is a very smart business strategy. Because by finding VLSI faults fast, diagnosing them accurately, and using the information to eliminate defects at their source, you'll get new, advanced products to market more efficiently.

With brain power like this, even difficult test problems become easy to solve. You'll start testing fast with low operating costs and highest circuit board yields at system assembly.

So if you're thinking about a new combinational tester, make a smart call. Contact Daryl Layzer at 617-482-2706, Ext. 2808 for more information about the new L350 VLSI Board Test System.

TERADYNE

CIRCLE NO. 55

Taking BiCMOS SRAM technology to 0.8 microns is our business.

Exploiting it is yours.

Rev up your system clocks.

Here are the world's fastest 8K x 8 SRAMs, leading our family of 64K BiCMOS SRAMs, with access times of just 12 ns.

Rev up your assembly. This is production BiCMOS with proven production yields, run on the same Cypress Semiconductor fab lines that have been cranking out millions of 0.8 micron CMOS parts for years.

Save on cost and real estate.

World's Fastest.

These parts are available in 300-mil-wide plastic DIP, as well as ceramic DIP, SOJ, and LCC.

Simplify expansion. The CY7B160, with on-chip memory decoding, lets you build memory 64K deep with no speed, space or power penalities.

Save on power. You get our proven, cool, low-power, high performance CMOS, integrated with bipolar gates in the critical speed paths, for a part that sets new records in high density SRAM performance.

Simplify your qualification process with our complete family of highest performance CMOS and BiCMOS SRAMS. Including seven different 64K BiCMOS parts, in 16K x 4 and 8K x 8 organizations.

Start now, just by calling for our 1990 Data Book. It's yours, free, for a fast phone call.

CY7B160, 16K x 4 On-Chip Decode

CY7B161, 16K x 4 Separate I/O

CY7B162, 16K x 4 Separate I/O

CY7B164, 16K x 4 Common I/O

CY7B166, 16K x 4 Common I/O, OE

CY7B185, 8K x 8

CY7B186, 8K x 8

Call today to get your 1990 Data Book. Hotline: 1-800-952-6300,* Ask for Dept.C45

CYPRESS SEMICONDUCTOR

*1-800-387-7599 in Canada. (32) 2-672-2220 in Europe.
©1990 Cypress Semiconductor, 3901 North First Street,
San Jose, CA 95134. Phone: (408) 943-2600,
Telex: 821032 CYPRESS SNJ UD, TWX: 910-997-0753.

EDITORIAL

You can pick winners

As you read this, EDN is starting an awards program that will recognize innovative new products as well as the most innovative engineer or engineering team in our industry. But the awards aren't EDN's alone. *They're your awards*, and we need your help to make them successful. You can help now by nominating products and people for awards and later by voting for the most innovative products and people in the industry.

All too often, innovative products and people don't get the recognition they deserve. Few people outside our industry know what we do or how we affect their lives. They use their appliances, telephones, VCRs, and other electronic gadgets without understanding the importance of electrical and electronic engineering in bringing those products to market. We at EDN believe this situation must change. Our awards are a start toward broader recognition for the exciting products our industry designs and manufactures and the people who bring these products and technologies to life.

In late 1990, we'll select one person or design team for the "EDN Innovator of the Year" award. *But, it's up to you and your coworkers to nominate the people or teams we should consider.* You can nominate yourself, too. In any case, you'll have to tell us what makes your nominee special enough to be the most innovative person in our industry.

Be sure to nominate products, too. Yes, they can be your company's products. We plan to award "EDN Innovation of the Year" awards in as many as six categories: semiconductors and integrated circuits, computers and peripherals, computer-aided engineering, hardware and interconnect, software, and components. Again, we'll need to know what makes the products you nominate particularly innovative.

After our editors screen all the entries, we'll give you a chance to vote—but first, we need your entries. To request a complete set of rules and entry forms, call us at (617) 558-4681 or (617) 558-4400, fax us at (617) 558-4470, or drop us a note at EDN Innovation Awards, 275 Washington St, Newton, MA 02158. All entries must reach us by June 15, 1990.

Oh, yes—there's one last thing you can do to help us recognize the innovations and innovators who make this industry so exciting. You can attend our awards banquet this fall.

Jon Titus

Jon Titus
Editor

INNOVATION
Driving Electronic Technology Into The Next Century

Jesse H Neal
Editorial Achievement Awards
1987, 1981 (2), 1978 (2),
1977, 1976, 1975
American Society of
Business Press Editors Award
1988, 1983, 1981

PRESENTING A SLI
PERSPECTIVE ON EP

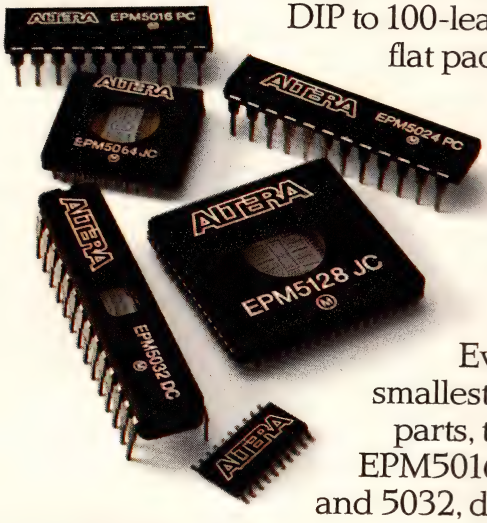
Think of it. PAL® speed and FPGA density in a CMOS EPLD.

The MAX™ EPLD from Altera.

MAX is the first family of programmable logic devices that provides both high speed and high logic density.

Which means MAX can handle just about all your designs. From simple address decoders to complex microprocessor peripherals.

Here's all the proof you need. Logic delays to 15ns. True clock rates to 100MHz. Logic densities up to 192 macrocells. In packages from 20-pin DIP to 100-lead quad flat packs.

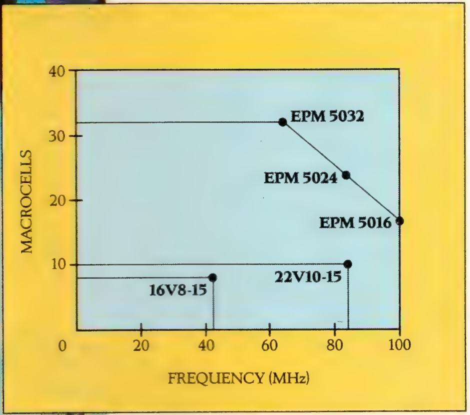


Even the smallest MAX parts, the EPM5016, 5024 and 5032, deliver two to four times more logic than the largest PALs. In fact, our EPM5016 offers 200% more logic than a 16V8 and 60% more than a 22V10. Plus higher speed and lower total power. All in a 20-pin part.

MAX and MAX+PLUS are trademarks of Altera Corporation. PAL is a registered trademark of Advanced Micro Devices.

GHTLY DIFFERENT LD PERFORMANCE.

But most importantly, MAX EPLDs really scream at the system level. Their higher integration boosts in-system performance by eliminating multi-chip delays. Helping your design cross the finish line before your competition even gets out of the gate.



Best of all, MAX gives you this unbeatable performance in record time. All thanks to Altera's powerful, easy-to-use MAX+PLUS™ software and popular third-party design tool support.

So give your next design all the horsepower it deserves. Talk to the folks who invented the EPLD.

Call Altera today at (408) 984-2800 for details. And take your logic design to the MAX.

ALTERA

2610 Orchard Pkwy., San Jose, CA 95134-2020
Tel. (408) 984-2800   Fax. (408) 248-6924

© 1990, Altera Corporation.

CIRCLE NO. 56

Applied Microsystems Corporation
Five Types of Transparency
Applied Microsystems Corporation
Selecting the Correct Development Tools
Applied Microsystems Corporation
Using the ES-1800 Event Monitor System
Basics of High Speed Digital Design
Applied Microsystems Corporation
Emulation in a Multiprocessor Environment
Applied Microsystems Corporation
What to Look for in an Emulator

Before you buy development

One glance at the advertising in this magazine and you know your embedded design involves mega choices. But too much of a good thing may lead to one thing: confusion.

We can help clear this up, for free. With the articles and technical notes you see above.

Because whether you're an old hand or just starting out, they'll provide timely insights and techniques. To help you get to market first.

Learn which development tools are right for your project. Do you need emulation or simulation? And just how can you debug less and enjoy it more.

These papers are based on Applied Microsystems' experience at setting up over 12,000 systems

© 1990 Applied Microsystems Corporation, P.O. Box 97002, Redmond, WA 98073-9702 USA. All rights reserved. AMC-9. Other names indicated by ® are registered trademarks of their respective holders.
For the name of your nearest distributor in Europe, call 44-(0)-296-625462. Europe Fax 44-296-623460. Or contact Applied Microsystems Corporation, Ltd., Chiltern Court, High Street, Wendover,

rosystems Corporation
A Review of Three Source Level Debuggers for Intel 16-bit Processors
Applied Microsysten
Applied Microsystems Corporation
Programming the Intel Peripheral Control Block
Applied Microsystems Corporation
Installation Checklist
ation
Networked Development Systems
Applied Microsystems Corporation
plied Microsystems Corporation
Statistical Performance Analysis
Applied
plied Microsystems Corporation
Training Program

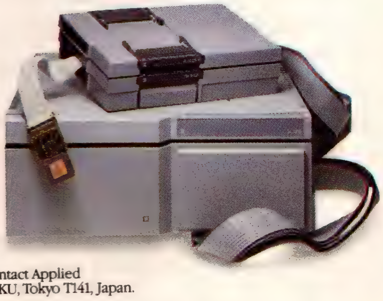
tools, read the fine print.

worldwide for 8-, 16- and 32-bit designs. Our field engineers have seen enough to write a book.

But we've boiled some of it down to several thousand well-chosen words.

To order an article, or to receive a system demonstration, call 1-800-343-3659.

And get the bigger story.



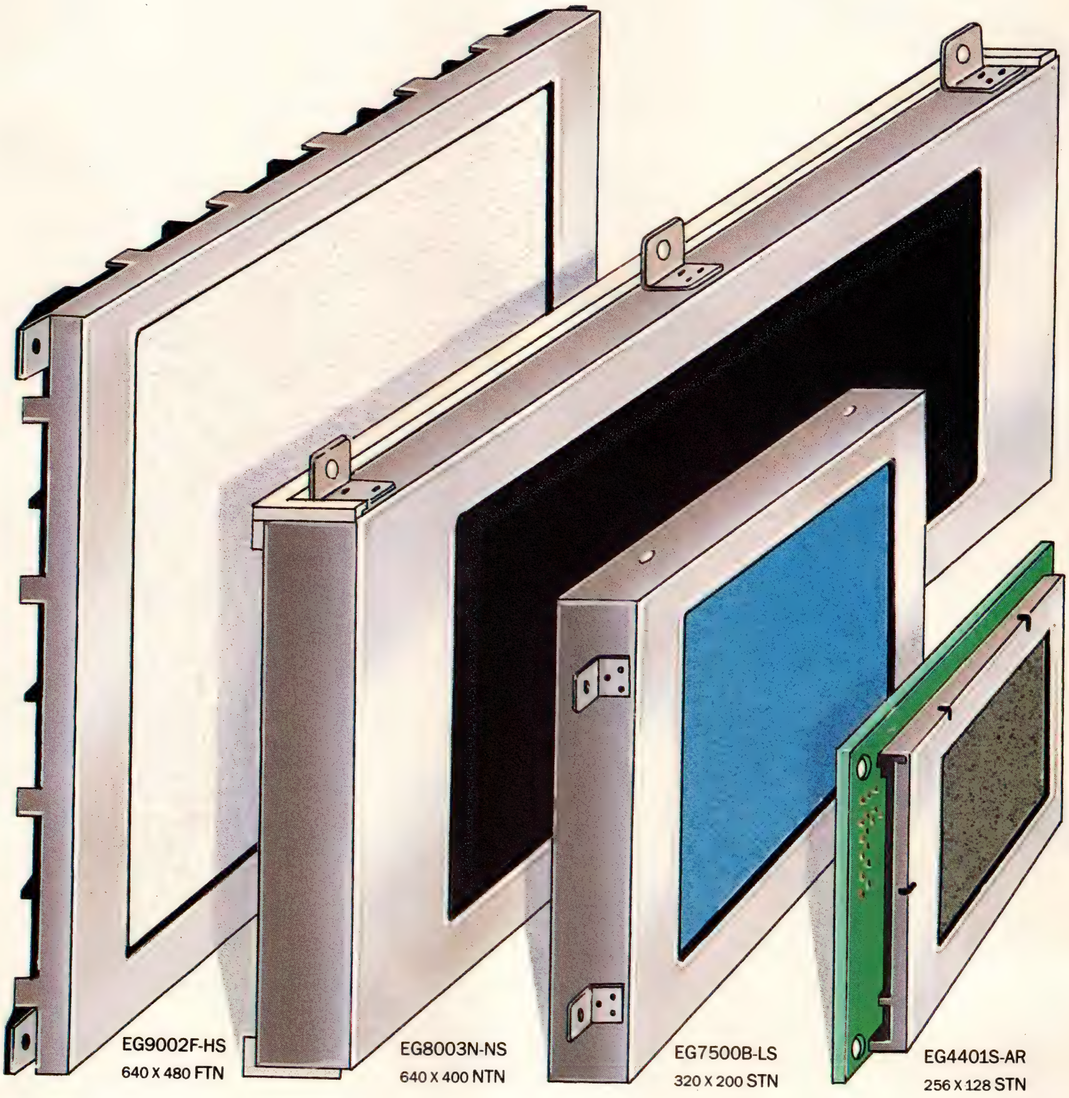
Applied
Microsystems
Corporation

Aylesbury, Bucks, HP22 6EP, England. **In Japan, call 03-493-0770.** Japan Fax 03-493-7270. Or contact Applied Microsystems Japan, Ltd., Nihon Seimei, Nishi-Gotanda Building, 7-24-5 Nishi-Gotanda, Shinagawa-KU, Tokyo T141, Japan.

CIRCLE NO. 57

SOLUTIONS IN PERFECT PROPORTION

FROM EPSON OEM



From large VGA resolution **LCD MODULES** to small alphanumeric displays, Epson has a solution in perfect proportion for your newest product application. The EG series of graphics display panels are available in 92 configurations ranging from 640 X 480 dots to 128 X 64 dots. A choice of super-twisted STN, page-white NTN or the latest in single film FTN technologies provides high-contrast and wide-angle viewing that rival the more traditional CRT. The popular EA-D series of alphanumeric modules come in 8 sizes from two lines of 40 characters to one line of 16 characters with a choice of EL or LED backlighting. Featuring low power consumption and unique chip-on-flex drivers in a compact, lightweight design Epson LCDs are ideal for applications ranging from handheld and laptop computers to point-of-sale displays and telecommunications terminals. For additional product information and detailed specifications, please contact your nearest Epson OEM sales office.

EPSON
AMERICA, INC
OEM DIVISION

San Francisco 408/257-6730 ■ Los Angeles 714/768-7474 ■ Chicago 815/455-7630 ■ Atlanta 404/552-1150
Boston 617/245-8007 ■ Vancouver 604/421-8008 ■ Toronto 416/479-8866 ■ Montreal 514/331-7534

CIRCLE NO. 58

Analog
TECHNOLOGY

Handheld DMMs shine despite ill treatment

Today's handheld DMMs survive electrical misuse and rough handling. But to obtain valid measurements, you will need to study the DMM's limitations.

Brian Kerridge,
European Editor

The modest handheld DMM is often the first thing you reach for to check the health of your designs. Frequently though, this overfamiliarity jeopardizes the health of the DMM itself. You can all too easily apply line voltage across the input of a meter you've set to measure current. You can just as easily douse the unit in coffee or send it spinning to the floor, further diminishing its chances for survival.

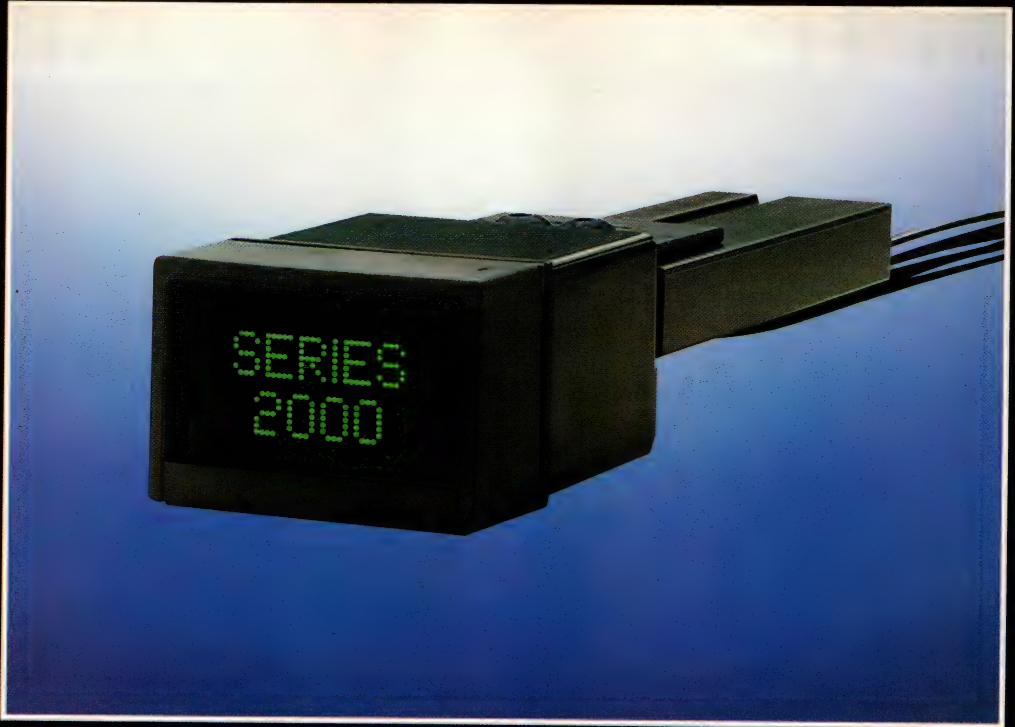
Vendors now offer ruggedized and electrically robust models that accept this punishment. Measurement performance is still limited though, but used with understanding, handheld DMMs provide a valuable first look at your circuit's performance.

Three-and-a-half-digit models are still the most popular ones in vendors' catalogs, an acknowledgment that this scale length suits most applications. Four-and-a-half-digit models are available, but when you examine the extra accuracy they obtain across all functions, unless you need just additional resolution, you might have trouble justifying the expense.

Analog read-out scales proliferate and are not misplaced on digital instruments. They add valuable insight when observing signal trends. Secondary measurement functions abound, but don't let their glister mask your primary needs: measuring voltage, current, and resistance. Of these basic functions, probably the most-used one is a simple check for continuity.

With so many vendors jostling for business, DMM prices are competitive. Ninety-nine dollars buys you an instrument that comprehensively covers the three main functions. Spend $290 and you can have a ruggedized model with

***You can measure the true rms value of ac voltages** to 20 kHz with ABB/Metrawatt/Goertz's M2008. The analog readout emulates a moving-pointer meter.*



The program in a switch.

Introducing Vivisun Series 2000, the programmable display pushbutton system that interfaces the operator with the host computer. The user friendly LED dot-matrix displays can display any graphics or alpha-numerics and are available in green, red or amber. They can efficiently guide the operator through any complex sequence, such as a checklist, with no errors and no wasted time.

They also simplify operator training as well as control panel design. Four Vivisun Series 2000 switches can replace 50 or more dedicated switches and the wiring that goes with them. In short, Vivisun Series 2000 gives you more control over everything including your costs.

Contact us today.

AEROSPACE OPTICS INC.
3201 Sandy Lane, Fort Worth, Texas 76112
(817) 451-1141 · Telex 75-8461 · Fax (817) 654-3405

SERIES
VIVISUN 2000™

Programmable display switches. Making the complex simple.

CIRCLE NO. 59

***You can safely drop Beckman Industrial's HD153 repeatedly** from 10 ft to a concrete floor. The instrument will also survive overloads of 1500V (6-kV transients) to the voltage ranges, and 500V and 15A to the resistance and current ranges, respectively.*

a back-lit 4½-digit display, true-rms ac, plus a range of secondary features such as temperature, frequency, capacitance, and pulse measurement. **Table 1** shows some of the instruments discussed in this article, along with their specifications and features.

Portability, light weight, and aerodynamic styling cause handheld DMMs to take flight occasionally. Earlier generations of sky-diving DMMs were one bounce away from the trash can. Not so for the ruggedized versions that now appear in the catalogs of some vendors. Drop figures of 10 ft boldly appear in specifications. Beckman Industrial's HD153 claims to be drop-proof against repeated tumbles. It also, in line with Fluke and Hewlett-Packard's ruggedized versions, meets the environmental demands of MIL-T-28800D for Class 2 equipment. No model claims to be waterproof. But for protection against sprayed liquid contaminants, O-ring seals fitted to the DMM's selector switch, terminals, and case safeguard the innards. Cases constructed from fire-resistant thermoplastic retain their looks even after an occasional brush with a hot soldering iron.

Also important in prolonging a DMM's life is defense from inadvertent stabs of electrical overload. Protection levels as high as 1200V—to all ranges of dc and ac voltage—are now commonplace. Such protection is not difficult for DMM designers to achieve, because the 10-MΩ input attenuator comfortably dissipates most of the overload. Similarly, to safeguard the resistance ranges, designers place a positive temperature-coefficient thermistor in series with the terminals for this function. Upon overload, this component absorbs the strain and allows you to abuse the input to 500V. Current ranges are the tricky ones to preserve, because for the DMM to measure current, there must be an almost direct connection from the terminals to the low-resistance internal shunts. Series-connected fuses prevent the DMM from catching fire when you apply heavy overloads, but the fuses may not open rapidly enough to offer complete protection. Fluke's 80 series offers you some comfort by sounding an alarm whenever the DMM senses a connection to its current terminal while the instrument is set for a noncurrent measurement. Often though, the use of both high- and low-current fuses maximizes the chances of a DMM's survival. Check carefully because some DMMs omit protection to the 10A range in an attempt to lessen the burden voltage—the IR drop across the meter's terminals during a current measurement.

Having examined the DMM's accuracy specifications, you should be conscious of further errors brought about by the effects the DMM has on the signal source. Additional errors caused by an imprudent measurement can easily swamp the accuracies stated in the vendor's catalog. A major cause of these errors is the DMM's finite input impedance, which for dc-voltage ranges is approximately 10 MΩ. Although for most tests this loading error is small, casual probing in circuitry with signal-source resistance to 1 MΩ produces errors of 10%. Models from CG Instruments and Hewlett-Packard feature input impedances above 1 GΩ, but only on the companies' 300-mV range devices. Contrast this with the 10-GΩ input impedance at 10V levels common on benchtop DMMs, and you can see that handheld DMMs are not substitutes.

On ac voltage ranges, most models have an input impedance of 10 MΩ shunted by 100 pF. In this respect, handheld DMMs are superior to the best long-scale DMMs, which normally have 1-MΩ input impedance. The reason that handheld DMMs can have higher input resistances on their ac ranges than benchtop units is that top-class DMMs have flat frequency response to 1 MHz, whereas the smaller instruments have lower bandwidth. Designing wideband amplifiers with tightly controlled frequency response and impedance levels above 1 MΩ is unpredictable due to internal stray capacitances. With handheld DMMs, lower accuracy is coupled with much lower bandwidth, allowing the 10-MΩ figure to be realized. Though these facts bode well for loading purposes, they should also caution you to study the DMM's ac-voltage specification carefully to discover the frequency range over which the accuracy is valid. On most models, the input frequencies that can be measured with the specified accuracy must be between 50 and 500 Hz. Clearly, for ac-voltage measurements, many handheld DMMs limit you to power-line applications.

There are exceptions, however. The ABB-Metrawatt M2008 and Fluke's series 80 models are both specified for audio signals of 45 Hz to 20 kHz. CG Instruments quotes an 80-kHz upper-frequency capability. Philips 18 series reaches 100 kHz, but it does so at the expense of input impedance, which the company vaguely specifies as greater than 2 MΩ. Also worthy of note is that extended frequency response does not apply to the alternating-current function, where for all models, the range is no greater than 40Hz to 400Hz.

You should also pay attention to the effects the DMM has when it monitors direct and alternating current. The voltage developed across the DMM's current-shunt and internal connections is typically 0.6V when measuring 10A. If the current being measured is sourced from a 5V power supply, for example, then an error of 10% will result. To minimize this burden-voltage effect, as mentioned, some units omit the fuse protection on the 10A range. This tradeoff is only reasonable if you watch for smoke signals. The 10A

Table 1—Representative handheld DMMs

			DC voltage		AC voltage			
Manufacturer	**Model**	**Full scale** (digits)	**Ranges**	**Basic accuracy** (% reading +digits)	**Ranges**	**Basic accuracy** (% reading +digits)	**Frequency range**	**Sense**
ABB Metrawatt/Goerz	M2008	3100	300 mV to 1000V	0.1+1	300 mV to 1000V	0.75+3	15 Hz to 20 kHz	True rms
B&K Precision	2860	1999	200 mV to 1000V	0.5+1	200 mV to 750V	1.25+4	40 Hz to 500 Hz	Mean
Beckman Industrial	HD153	1999	200 mV to 1500V	0.25+1	200 mV to 1000V	0.75+3	45 Hz to 1 kHz	Mean
CG Instruments	3255	3199	300 mV to 1000V	0.4+1	3V to 750V	1+3	40 Hz to 1 kHz	Mean
	3430	24,999	250 mV to 1000V	0.04+2	250 mV to 750V	0.5+10	20 Hz to 80 kHz	True rms
Cirkit	TM175	1999	200 mV to 1000V	0.5+1	200 mV to 750V	1+4	50 Hz to 500 Hz	Mean
Fluke	83	3999	400 mV to 1000V	0.3+1	400 mV to 1000V	1.5+3	45 Hz to 5 kHz	Mean
	87	19,999	400 mV to 1000V	0.1+10	400 mV to 1000V	1+20	45 Hz to 20 kHz	True rms
Goldstar Precision	DM7333	1999	200 mV to 1000V	0.3+1	200 mV to 750V	0.5+3	50 Hz to 600 Hz	Mean
	DM8243	19,999	200 mV to 1000V	0.05+4	200 mV to 750V	0.5+10	50 Hz to 600 Hz	Mean
Hewlett-Packard	E2373A	3199	300 mV to 1000V	0.7+1	3V to 750V	1.2+4	40 Hz to 1 kHz	Mean
	E2378A	3199	300 mV to 1000V	0.4+1	3V to 750V	1+3	40 Hz to 1 kHz	Mean
Philips	2518	19,999	1V to 1000V	0.1+2	1V to 1000V	0.5+10	40 Hz to 40 kHz	True rms
	2718	19,999	1V to 1000V	0.04+2	1V to 1000V	0.3+10	40 Hz to 100 kHz	True rms
Tegam	132	1999	200 mV to 1000V	0.25+1	200 mV to 750V	1+9	45 Hz to 500 Hz	True rms
Universal Enterprises	DM380	1999	200 mV to 1000V	0.5+1	200 mV to 700V	0.8+2	40 Hz to 500 Hz	Mean

***Note:** N/A = not applicable.

input ceiling results from a thermal limitation in the internal current shunt (usually 0.05Ω). ABB-Metrawatt's model M2008, Fluke's 80 series and Philip's 2718 let you measure 20A, but only for 30 seconds. Bear in mind that at this level the shunt is dissipating 20W, so don't be tempted to prolong the time limit. Also, don't expect the reading to settle in this period—the self-heating of the shunt will be changing its value rapidly.

A handheld DMM's highest accuracy is around 0.05%. This figure appears in the specification of 4½-digit (19,999-scale-length) models, but it represents 1 part in 2000 and neatly explains why 3½ digits (1999 counts) are adequate. There may be applications where extra resolution (the ability to discern smaller signal changes) is useful, but extra resolution has little to do with accuracy. Generally, when a vendor offers you an extra digit (10 times the resolution), the increased resolution will not be matched by a similar increase in accuracy. A three or four times improvement is typical. At best, for dc-voltage and resistance functions, 3½-digit models offer you 0.2% accuracy with 0.05% resolution; 4½-digit versions have 0.05% accuracy with 0.005% resolution. On ac-voltage, direct, and alternating-current ranges, the lack of advantage with 4½ digits is more striking, because the measurement accuracy barely improves by two times over 3½ digit alternatives.

Digital is not always best

Analog indicators have merit, and several DMMs make innovative use of an auxiliary bar-graph display to ease your measurement task. Deciphering a digital readout when you want to null, peak, or zero a signal is a pain. Essentially, analog displays let you view a

Resistance		Current					
Ranges	Basic accuracy (% reading +digits)	Ranges	Direct current basic accuracy (% reading +digits)	Alternating current basic accuracy (% reading +digits)	Secondary functions	Ruggedization	Price
300Ω to 30 MΩ	0.2+1	300 μA to 10A	0.75+1	1.5+4	Range, data, and peak hold; temperature	N/A*	$409
200Ω to 20 MΩ	0.75+4	200 μA to 10A	1+4	5+3	Diode	Sealed case; drop-proof to 5 ft	$99
200Ω to 20 MΩ	0.5+2	20 mA to 10A	0.75+1	1.5+2	Range hold, diode, logic pulse	Sealed case; drop-proof to 10 ft	$220
300Ω to 30 MΩ	0.7+1	300 μA to 10A	1+2	2+5	Range, data, and peak hold; diode; temperature	Sealed case	$170
250Ω to 25 MΩ	0.06+2	250 mA to 10A	0.25+2	0.75+10	Range, data, and peak hold; temperature; frequency; dB	N/A	$400
200Ω to 2 GΩ	0.8+1	200 μA to 10A	1+1	1.2+4	Diode, frequency, temperature, capacitance, h_{fe}, logic pulse	N/A	$85
400Ω to 40 MΩ	0.4+1	400 μA to 10A (20A)	0.4+2	1.2+2	Range, data, and peak hold; max/min and average; diode; frequency; capacitance	MIL-T-28800D Class 2	$199
400Ω to 40 MΩ	0.2+10	400 μA to 10A (20A)	0.2+20	1+20	Same as model 83	MIL-T-28800D Class 2	$289
200Ω to 20 MΩ	0.5+1	2 mA to 10A	0.5+1	1+3	Diode, frequency, capacitance, h_{fe}	N/A	$100
200Ω to 20 MΩ	0.2+2	2 mA to 10A	0.3+2	0.75+10	Same as model 7333, plus data hold	N/A	$130
300Ω to 30 MΩ	0.7+1	300 μA to 10A	1+2	2+5	Diode	N/A	$99
300Ω to 30 MΩ	0.7+1	300 μA to 10A	1+2	2+5	Data hold, diode, temperature	MIL-T-28800D type III Class 2	$189
1 kΩ to 100 MΩ	0.3+10	20 mA to 10A (20A)	0.5+10	0.8+10	Range, data, and peak hold; relative; diode; temperature; dB	N/A	$275
1 kΩ to 100 MΩ	0.15+5	20 mA to 10A (20A)	0.4+10	0.6+10	Same as model 2518, plus max/min, logging, frequency, and logic pulse	N/A	$379
200Ω to 20 MΩ	0.2+1	2 mA to 10A	0.75+1	2+9	Diode, temperature	N/A	$229
200Ω to 20 MΩ	0.5+1	20 μA to 10A	0.5+1	1+2	Range, data, and peak hold; diode; h_{fe}; temperature	Sealed case; drop-proof to 7½ ft	$170

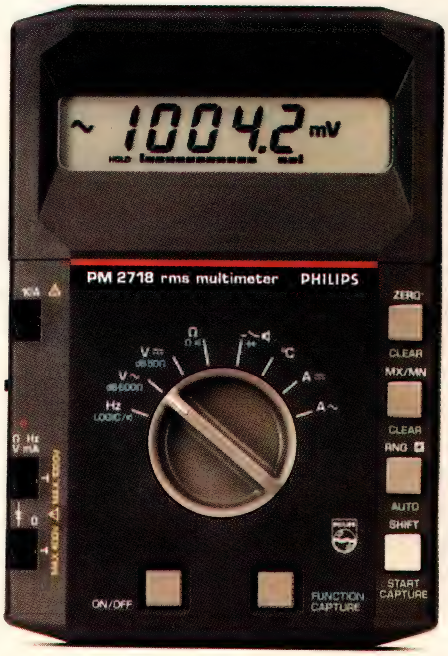
trend, which improves your tweaking judgment. Whereas digital displays refresh at 3/sec, analog scales update between 12 and 40/sec, assisting your response and producing a realistic analog-meter effect. In fact, ABB-Metrawatt's model 2008 and Fluke's 80 series present you with a graduated scale, along which a fine pointer travels. The scale and the pointer emulate early analog meters and should be popular with old-timers. The 2008 also shows a 10% slice of the scale below the 0V point to aid zeroing.

Fluke and Philips models let you store an offset equivalent to the input signal, thereafter displaying deviation about that set-point. You can change ranges and zoom in for more sensitivity. Philips additionally provides a single but nonlinear scale with a span of ±20%; the center segments let you resolve to 0.3%. Beckman Industrial's HD153 employs audio-analog readout. The tone varies between 10 Hz and 2.5 kHz in sympathy with a zero to full-scale reading. This variation allows you to make level adjustments without looking at the meter. Also, the meter emits a crackling noise when an intermittent signal is detected—useful evidence of a bad joint when testing continuity.

John Fluke's true rms model 87 DMM is ruggedized and has a back-lit display. *It sounds an alarm when you push your leads into a current terminal that has a voltage function selected.*

If you're interested in functional embellishments, there's no shortage—even if you own a budget-priced handheld DMM. Diode testing is the most frequent addition, although this is simply the 1-kΩ range in disguise. A 1-mA source feeds the diode in the forward direction, and the display shows the diode's forward voltage drop. Another common feature allows you to log maximum and minimum readings. In some cases the beeper sounds when a new threshold level is stored. Fluke's 80 series adds an averaging memory with enough capacity for 36 hours worth of readings.

Some units feature temperature measurement, and depending on the model, accept input from two types of sensor. A K type (Chromel/Alumel) thermocouple is more popular, although with HP and Universal Enterprises DMMs you will need to purchase the vendors' sensor and external adapter. DMMs from CG Instruments and Tegam contain internal cold-junction compensation that let you wire up any standard K sensor directly. Temperature ranges cover −20° to +700°C. Philips opts for a platinum-resistance-thermometer (PRT) sensor that conforms to the 100Ω at 0°C standard, and so avoids the cold-junction compensation requirements of thermocouples. A PRT sensor is also inherently more linear than thermocouples and delivers a measurement scale from −250° to +1000°C with 0.1°C resolution.



The back-lit display on Philips' model PM2718 *automatically lights up in dim lighting. The analog scale lets you observe trends and enables fine adjustment to peak or null readings to 0.3% of range.*

If rough and ready frequency measurement is what you need, four models shown in the **table** oblige. Except for Cirkit, which specifies 10 Hz to 10 MHz, the others limit the specified frequency to between 10Hz and 200 kHz at an accuracy of around 1%. Fluke's model 80s have tighter accuracy—to 0.01%.

When your R&D lab takes its next post-luncheon siesta, you can bring things back to life by firing up the DMM's logic-pulse function. Philips' model 2718 sounds a high note when probing a logical high, and a low frequency for a zero. Input a pulse train with widths down to 100 nsec and you will be rewarded with a series of beeps. Logic thresholds default to TTL

Some facts about accuracy

Vendors express a DMM's accuracy as a percentage of the reading plus a fixed number of digits of the DMM's scale. This method most closely describes the behavior of the measurement circuitry, but it also means that you must consider the following related factors in determining the accuracy at all points of the scale: percent of reading plus the number of digits specified, and the full-scale number of digits.

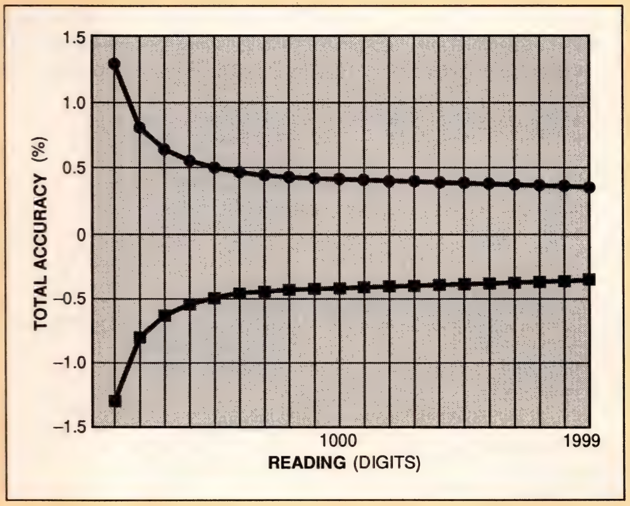
The percentage-of-reading element allows for errors proportional to the magnitude of the input signal, such as in the gain-defining resistor networks and the internal reference. The number-of-digits component in the accuracy expression covers fixed-magnitude-voltage errors, such as zero offsets in the various stages of the DMM's analog channel. Although fixed in voltage, the contribution these errors make to the total percentage accuracy of the instrument varies with the full-scale number of digits—1 digit in 1999 yields 0.05%, whereas 1 digit in 19,999 is 0.005%.

To make a comprehensive accuracy comparison of one DMM against another, what you really want to know is the total percentage error at all points across the scale. The only way to gain this overall impression is to use a graphical method. The plot shown in **Fig A** assumes a typical handheld DMM's specification to be 0.3%+ 1 digit. What the graph clearly shows is the effect of the seemingly innocuous ±1 digit. Below the midrange point this 1 digit dominates total accuracy and at one tenth of scale the inaccuracy of the DMM doubles. If the ±1 digit increases to 3 or 4 digits, as it does with some ac-voltage specifications, this effect is even more marked. Couple this with a different percentage of reading term from model to model, and you'll find that a graph is the best method for comparing accuracies.

Observe also that for the same specification, models with full-scales above 1999 digits give you the advantage of lower total accuracy over a much wider section of scale. In addition, the extra resolution of a 3199-count meter will let you resolve a 0.1V change in a 240V ac line voltage. With a 1999-count meter, you can resolve changes no smaller than 1V.

Another factor affecting ac voltage and current accuracy is the method used for converting ac to dc within the DMM. A true rms representation of an alternating signal is deemed the most useful, because it more closely describes the waveform's power capacity. However, for simplicity, most handheld DMMs use a mean-sensing converter, but display rms values using a "fiddle" factor. This factor, 1.11, is only valid when the input is a pure sine wave. In many applications where you employ a handheld DMM, the measured waveform isn't sinusoidal, and the signal may easily contain a total harmonic distortion of 1%. This error will be 3% if a mean-sensing detector is employed. This error is large and adds to the typical 1% accuracy for the DMM alone.

The solution? Choose a true-rms-sensing handheld DMM. Even then, however, all your worries are not over. Certainly, rms converters eliminate the 3% error just cited, but if the input is severely distorted—a high mark-to-space-ratio square wave, then further errors arise. These errors result from the dynamic limitations in the rms converter. You will find a figure of merit describing this, called "crest-factor"(CF), tucked away in the vendor's specifications. CF equals the peak to rms ratio of a waveform. A typical DMM's CF limit is 5, which means that sine-wave (CF = 1.4) and 1:1 square-wave (CF = 1) measurements incur no additional errors.



The ±1 digit portion of a DMM's 0.3%±1-digit accuracy specification *dominates total accuracy below the midrange point of the DMM's scale. Instruments with full-scale digits of 3999 minimize this effect, and with the same specification, give you lower total accuracy across a wider section of scale.*

levels. But if you initially measure V_{CC}, one stroke of the zero key sets new thresholds to 25% and 75% of V_{CC}. The display further indicates the nature of the input pulse by using different segments to describe positive or negative edges, 1:1 square waves, stuck lines and open circuits. Beckman Industrial's HD153 is equally vocal in this mode. It detects 50-nsec blips, but has a fixed-logic threshold of 2.6V.

Hewlett Packard's* *ruggedized E2378A meets the *environmental requirements of standard MIL-T-28800D, type III, Class 2, including 6-ft drop and 45° water-spray protection.*

Take that annual checkup

One aspect where suppliers are in total agreement is the need for accuracy recalibration every year. Don't overlook this maintenance. The gain-defining and reference elements of the DMM will show appreciable drift over 12 months and cause a corresponding accuracy shift. If your company follows the dictates of MIL-STD-45662A or NATO/OTAN AQAP 6, all test equipment, including lowly handheld DMMs, requires an annual checkup. Recalibration involves tweaking a few internal potentiometers when the unit is linked to a multifunction calibration source. Only Philips allows you to recalibrate automatically without opening the case.

Evolution of the handheld DMM is almost complete. The size and weight requires no change, accuracy is sufficient, and 1000 hours of battery power is acceptable. Back-lit LCDs are clear, ruggedized enclosures maintain health, and secondary functions advance.

Increased bandwidth on ac voltage would benefit some models. But, because most measurements are made at power frequencies, increasing the bandwith may not be necessary.

Warranties of three years and more are a welcome innovation and will encourage EEs to continue purchasing these products for private as well as professional use. **EDN**

Article Interest Quotient
(Circle One)
High 518 Medium 519 Low 520

For more information . . .

For more information on the handheld digital multimeters discussed in this article, circle the appropriate numbers on the Information Retrieval Service card or use EDN's Express Request service. When you contact any of the following manufacturers directly, please let them know you saw their products in EDN.

ABB-Metrawatt/Goertz GmbH
Thomas-Mann-Strasse 16-20
Postfach 1333
8500 Nuremburg 50
West Germany
FAX (911) 860-2669
Circle No. 700

B&K Precision/Maxtec Int Corp
6470 West Cortland St
Chicago, IL 60635
(312) 889-9087
Circle No. 701

Beckman Industrial Corp
200 Parkside Dr
San Francisco, CA 91340
(818) 365-8131
FAX (818) 365-1876
Circle No. 702

CG Instruments
434 Windsor Park Dr
Dayton, OH 45459
(513) 434-6952
FAX (513) 434-7643
Circle No. 703

Cirkit
Park Lane
Broxbourne EN10 7NQ UK
FAX (992) 464457
Circle No. 704

John Fluke
Manufacturing Co Inc
6920 Seaway Blvd
Everett, WA 98206
(206) 356-5500
FAX (206) 356 5108
Circle No. 705

Goldstar Precision
13013 East 166th St
Cerritos, CA 90701
(213) 404-0101
FAX (213) 926-0849
Circle No. 706

Hewlett-Packard
Box 301
Loveland, CO 80539
(303) 679-5000
FAX (303) 679-5950
Circle No. 707

Philips
Industrial and Electro-acoustic
Systems Div
Box 218
5600 MD Eindhoven
The Netherlands
(40) 786280
FAX (40) 785968
Circle No. 708

Tegam
7230 North Ridge Rd
Madison, OH 44057
(216) 428-7505
FAX (216) 428-1068
Circle No. 709

Universal Enterprises Inc
5500 SW Artic Drive
Beaverton, OR 97005
(503) 644-8723
FAX (503) 643-6322
Circle No. 710

Image Processing for the PC AT or PS/2. Software identical in every respect.

—Fred Molinari, President

QuickCapture gives you a choice of host platforms.

Now you can keep your options open when it comes to choosing a computer platform for image processing.

Because QuickCapture™ on the PC AT® and PS/2™ is strictly software, file, and function compatible.

Just think, applications developed on one machine can be used instantly without modification on the other.

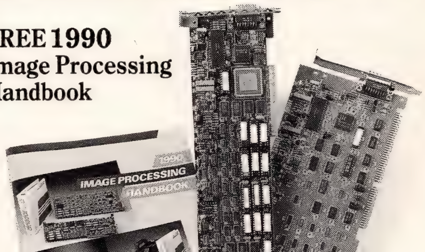
So, add QuickCapture to your choice of platform and you've just added the industry's most versatile frame grabber for all your scientific and commercial applications.

QuickCapture for the PC AT or PS/2. The likeness is uncanny.

	DT2953	DT2855
640x480 resolution	yes	yes
Input/Output LUTs	yes	yes
Input type	RS-170, NTSC	RS-170, NTSC
File formats	TIFF, PCX	TIFF, PCX
Compatible bus	MCA	PC AT

Call (508) 481-3700
In Canada, call (800) 268-0427

FREE 1990 Image Processing Handbook



DATA TRANSLATION®

World Headquarters: Data Translation, Inc., 100 Locke Drive, Marlboro, MA 01752-1192 USA, (508) 481-3700 Tlx 951646
United Kingdom Headquarters: Data Translation Ltd., The Mulberry Business Park, Wokingham, Berkshire RG11 2QJ U.K. (0734) 793838 Tlx 94011914
West Germany Headquarters: Data Translation GmbH, Stuttgarter Strasse 66, 7120 Bietigheim-Bissingen, West Germany 07142-54025
International Sales Offices: Australia (2) 662-4255; Belgium (2) 466-8199; Canada (416) 625-1907; China (1) 868-721 x4017; Denmark (42) 274511; Finland (0) 372144; France (1) 69077802; Greece (1) 361-4300; Hong Kong (5) 448963; India (22) 23-1040; Israel (52) 545685; Italy (2) 82470.1; Japan (3) 502-5550, (3) 348-8301, (3) 555-1111; Korea (2) 756-9954; Netherlands (70) 99-6360; New Zealand (64) 9-545313; Norway (2) 53 12 50; Portugal (1) 545313; Singapore (65) 7797621; South Africa (12) 8037680/93; Spain (1) 455-8112; Sweden (8) 761-7820; Switzerland (1) 723-1410; Taiwan (2) 702-0405.

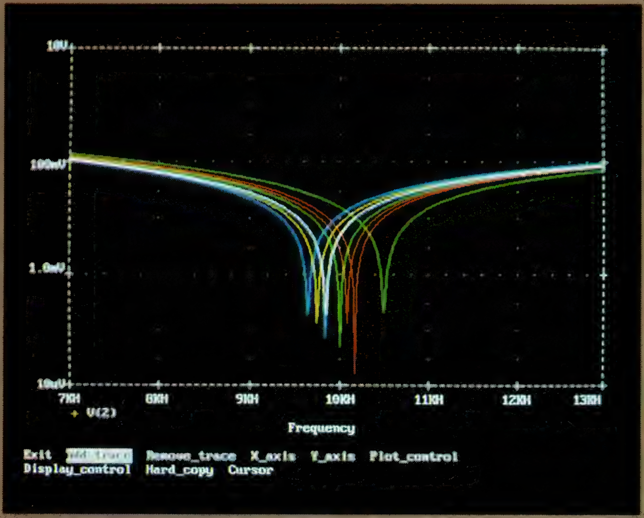
Data Translation is a registered trademark of Data Translation, Inc. All other trademarks and registered trademarks are the property of their respective holders.

CIRCLE NO. 60

PSpice

MicroSim Corporation

The Standard for Circuit Simulation



Response curves from Monte Carlo analysis of a notch filter

Statistical Analysis

PSpice's Monte Carlo option calculates the variations in a circuit's performance allowing for component tolerances. The option performs statistical analyses: Monte Carlo, Sensitivity, and Worst Case. This allows the circuits to be evaluated under "real world" conditions.

Since no one random distribution will suffice for all Monte Carlo applications, PSpice has two built-in distributions: uniform, and Gaussian. Also, arbitrary distributions may be specified by the user.

Multiple waveforms from the analyses can be viewed together to "eyeball" the spread of results. A summary of data is printed after all runs have completed. It lists values of a "waveform measure" in order by magnitude, plus such information as the mean and standard deviation of the lists.

Since its introduction over six years ago, MicroSim's PSpice has more copies sold than all other SPICE programs combined. PSpice has gained its reputation from its extensive capabilities, accuracy of results, diverse options, and range of available platforms. PSpice includes an extensive device library of 2500 analog parts and 1200 digital parts.

A wide variety of circuits can be analyzed using PSpice. They range from precision instrumentation amps, to microwave mixers, to switching power supplies, to digital control circuits. Our capability to analyze mixed analog/digital circuits is unique in the industry.

PSpice is available on these computer systems:

- The PC family, including the PS/2, running DOS, Protected Mode DOS, or OS/2.
- The Macintosh II family.
- The Sun 3, Sun 4, and SPARCstation families.
- The HP/Apollo DS2000, DS3000, and DS4000 series workstation.
- The DECstation 2100 and 3100.
- The VAX/VMS family, including the Micro VAX.

Each copy of PSpice comes with our extensive product support. Our technical staff has over 100 years of experience in CAD/CAE, and our software is supported by the engineers who wrote it.

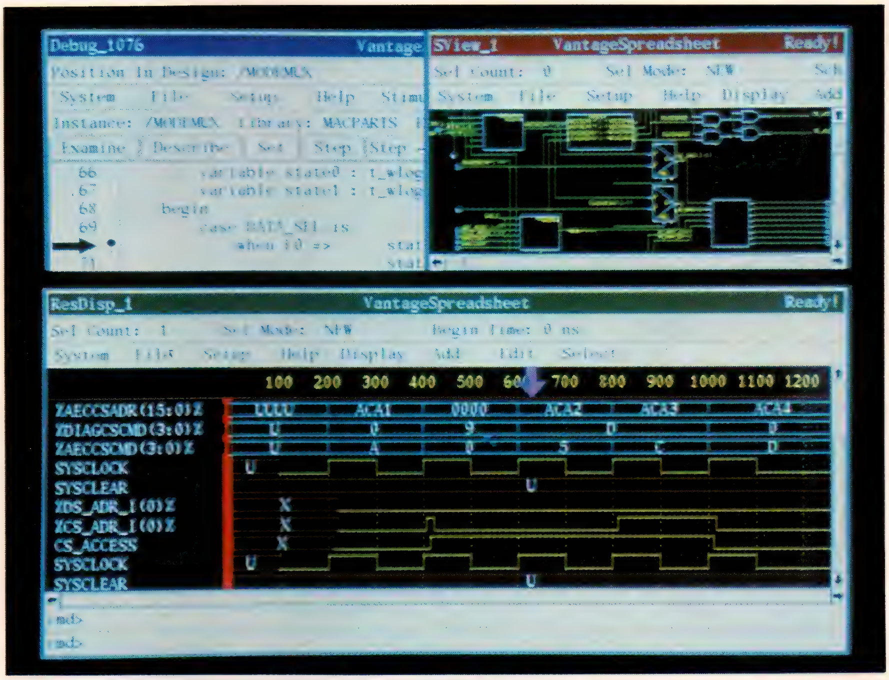
For further information about the Monte Carlo analysis option or any other PSpice product, please call us **toll free** at (800) 826-8603 or, in California, (714) 770-3022. Find out for yourself why PSpice has become the standard for circuit simulation.

20 Fairbanks • Irvine, CA 92718 USA • FAX (714) 455-0554

CIRCLE NO. 61

PSpice is a registered trademark of MicroSim Corporation. All other brands and product names are trademarks or registered trademarks of their respective holders.

Graphical VHDL source-level debugger executes and debugs pesky designs



***Watch the simulator exercise your circuit** by looking at either the VHDL description or the schematic using Debug 1076.*

If you could write perfect VHDL (VHSIC hardware description language) models, you wouldn't need a device like Debug 1076. Unfortunately, very few of us are so talented.

Because VHDL is a description language rather than a programming language, VHDL presents some interesting debugging problems that typical programming-language debuggers can't solve. Consider first that VHDL can execute multiple processes concurrently, where as most programming languages execute their code sequentially.

Also, programming languages don't normally understand simulation time, but VHDL does. For example, you might want to set a breakpoint at some future time in your simulation; to debug a programming language, you'd set a breakpoint at a statement or on a condition.

Debug 1076, a Motif-based source-level debugger, automatically tracks and lets you display concurrent events as they execute. You can examine the source code and simulation state of any component instance. When you want to evaluate components, you can set breakpoints on a specific component or on all instances of a component.

The mouse-driven graphical user interface lets you interact with VHDL objects like variables, signals, and parameters. You can also step through your source-code execution. When checking the execution of your description, you can set breakpoints either on execution of the source code or at specific simulation times.

Finally, because of the device's tight coupling with its underlying simulator, the VantageSpreadsheet, you can make incremental changes to either the VHDL source code or the schematic during debug operations while the simulator is running. (This set of programs will draw a schematic from a VHDL file.)

Debug 1076 is part of the upgrade to the VantageSpreadsheet simulator, which offers a full EDIF (Electronic Design Interchange Format) 2 0 0 schematic reader and writer. The programmer has also made changes to improve compilation and initialization times.

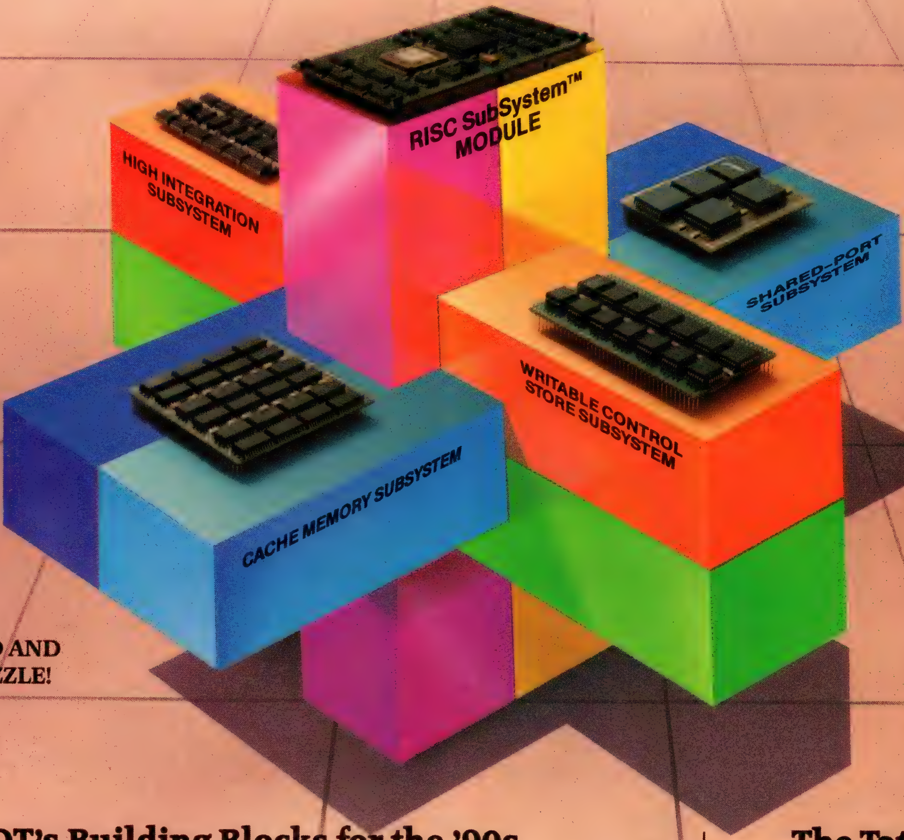
The debug software will be available for Apollo workstations by mid-June and for Sun workstations by mid-July, at a cost of $5000. For new users, the upgraded simulator, version 2.0, costs $44,000; for currently licensed users, version 2.0 is provided free of charge under their maintenance agreements.

—*Michael C Markowitz*

Vantage Analysis Systems Inc, 42840 Christy St, Suite 201, Fremont, CA 94538. Phone (415) 659-0901. FAX (415) 659-0129.

Circle No. 731

The Ultimate Building Blocks



**SEND IN THIS AD AND
GET A FREE PUZZLE!**

IDT's Building Blocks for the '90s

IDT is devoted to solving tomorrow's puzzles today. We recognize that our industry is changing rapidly and that future designs will require complex integrated functions using less board space. That's why IDT developed the Building Blocks for the '90s—subsystems to maximize functionality and performance while minimizing board space.

We've Figured it Out

We figure that you'll want subsystems for more than one application. IDT currently offers subsytems for cache and shared-port memories, writable control store, RISC CPU, and high-integration func-tions. But no one solution will completely solve every problem, so we will help you solve specific design dilemmas with custom subsystem designs. We can figure prominently in your design solutions—and we have the track record to prove it!

Putting It All Together

IDT's strategic mix of component products allows us to easily put all the pieces together. We draw from our extensive line of individual products and create custom components for our subsystems. We make sure that what you want in a subsystem is what you get.

Solving the Puzzle

And there's more! We do all the design, manufacture, testing, and burn-in on our subsystems. We guarantee our subsystems—all you have to do is plug them in. And we offer immediate availability for standard subsystems and deliver custom solutions in as fast as 6 weeks! At IDT, we believe in offering a total solution, not just pieces of the puzzle.

The Total Solution

Call our Marketing Hotline at **(408) 492-8551, Dept. UBB90** today for technical information. Or call (408) 492-8225 for a copy of our Subsystems Short-Form Catalog, Custom Subsystems Information Packet, and 1989 Data Book Supplement with details about all our subsystems, including RISC.

IDT, Corporate Marketing,
2975 Stender Way, Santa Clara, CA
95052-8015, FAX 408-492-8674.

When cost-effective performance counts

Integrated
Device Technology

Data-compression chip for mass-storage devices provides random access to files

The IC-105 chip provides data compression for mass-storage devices. To compress or decompress data, the chip must interface with two external 32k×8-bit static RAMs. One RAM is a buffer for data storage. The company's proprietary compression algorithm uses the other RAM as a dictionary.

This algorithm can compress and decompress blocks of data of varying lengths without resetting the dictionary. Using the algorithm, you can randomly access files on a mass-storage device. In addition, the algorithm doesn't require prior statistics on data strings that fixed-table approaches, such as Huffman coding methods, require. By generating decompressed data that is an exact reproduction of the original data, the algorithm achieves lossless or noiseless data compression. Thus, the algorithm maintains the data integrity that's essential to CAD and desktop-publishing applications.

The algorithm can identify unique substrings within a string of data and store the substrings in the dictionary as it compresses data. The algorithm achieves data compression by matching input data with substrings in the dictionary. To decompress data, the algorithm reverses the process. Because the algorithm creates the dictionary on the fly, it can adapt to any input data pattern.

The chip contains two timer/counters that it uses to monitor the input and output data rates. The counters permit the chip to automatically sense whether the output rate exceeds the input rate; an excess output rate indicates that the data is uncompressible. Under this condition, the chip sets a flag in one of the status registers. The software can then use this flag to bypass the compression algorithm.

The IC-105 chip can compress input data at a rate of 2M bytes/sec; it can decompress output data at a 5M-byte/sec rate; and it can handle burst rates at 10M bytes/sec. Mass-storage devices for which the chip compresses data include hard, floppy, and RAM disks; magneto-optical devices; and WORM (write once, read many) and tape-backup drives. Sample compression ratios include the following ranges: 4:1 to 15:1 for CCITT Group III documents; 3:1 to 8:1 for databases; 1.5:1 to 7:1 for image files; 2:1 to 12:1 for CAD/CAM files; 2:1 to 3:1 for word-processing files; and 1:1 to 2:1 for executable code.

The IC-105 operates at 40 MHz and has an interface port that an external 8-bit µP uses to control the IC. The interface port communicates with nine internal control registers in which the µP loads commands as well as the system configuration. Eight status registers report operation results, such as average compression and decompression ratios, to the µP.

The 35,000-gate-equivalent chip uses 1.2-µm CMOS technology. It consumes 200 mW during operation and has a power-down mode. The chip comes in either a 68-pin plastic leaded chip carrier or an 80-pin plastic quad fine-pitch package.

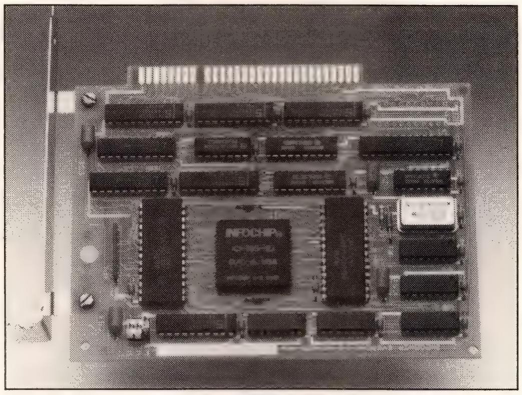
An 8-bit ISA bus half-size card, called the Disk Expander card, uses the IC-105 chip and required circuitry to operate in IBM PCs or compatible computers for running MS-DOS 3.X. The software that comes with the card eliminates the 32M-byte DOS barrier. This card monitors the host bus and uses firmware to intercept any data exchanges between the host CPU and a mass-storage device. The card compresses data at 1.5M bytes/sec, decompresses data at 4M bytes/sec, and handles burst rates at 10M bytes/sec. The card's operation is transparent to the user.

The IC-105 chip costs $49.95 (100,000). Delivery is stock to 90 days. The Disk Expander card sells for $199.

—John Gallant

InfoChips Systems Inc, 2840 San Tomas Expressway, Santa Clara, CA 95054. Phone (408) 727-0514. FAX (408) 727-4190.

Circle No. 732



The Disk Expander plug-in card for the 8-bit ISA bus *uses an IC-105 chip for mass-storage devices. The data-compression chip, in turn, provides a compression algorithm that permits random access to files.*

Switched-mode power-supply IC integrates switch, controller, and self protection

In addition to CMOS analog and digital power-supply control, the PWR-SMP3 integrates a 350V power MOSFET switch. Using this device, you can design a 3W, off-line, switching power supply into a very small space. The 16-pin DIP and external components, which include a bridge rectifier, a transformer, and input and output capacitors, can fit in a ½-in.^{3} space.

The IC operates over an input range of 90 to 140V ac and 36 to 200V dc. The turns ratio of your transformer will determine the output voltage of the supply. Depending on current and temperature conditions, the power MOSFET's on-resistance is typically 14 to 28Ω. At a drain voltage of 25V, the output capacitance is 8 pF.

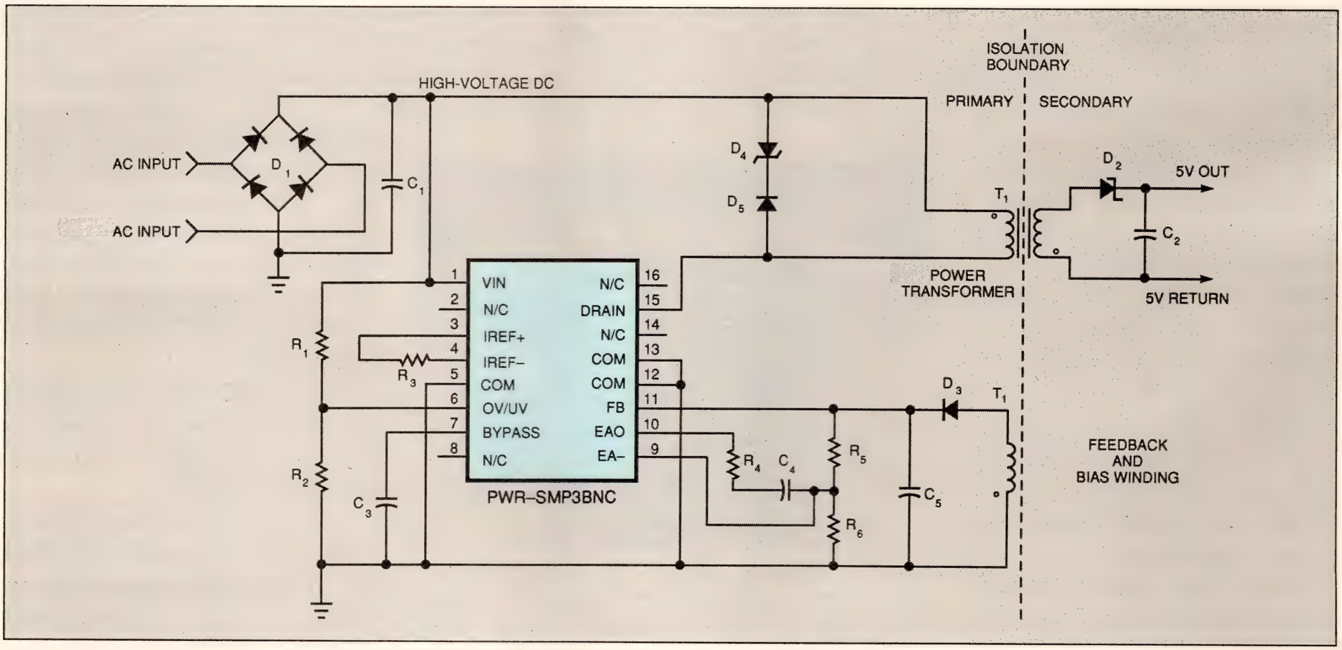
The device's controller section drives and controls the power MOSFET. Although the designers of the chip tailored it for use in flyback topologies, you can also use it to design other switching topologies. The controller consists of an off-line start-up preregulator that soft-starts the circuit, a 1-MHz PWM oscillator, a bandgap reference, an error amplifier, a gate driver, and protection circuits. The 1-MHz switching frequency enables you to use a smaller transformer and capacitors than you can in power supplies that operate at lower frequencies. The IC also contains feedback and compensation networks.

The IC implements four types of self protection. Overvoltage protection kicks in at inputs of more than 140V to ensure that the IC shuts down during line surges. The IC starts up again when the input returns to the proper input voltage range. Undervoltage lockout ensures that the input voltage and internal supply voltage are within specification before the chip operates. Overtemperature protection shuts down the device at 175°C max and allows the device to regulate when the temperature falls below this value. Finally, this device can withstand output shorts for extended periods without damage. An integrated current-limit comparator, a gate driver, and logic quickly respond to overcurrent conditions. The overcurrent threshold is typically 300 mA.

At an ambient temperature of 25°C, the IC dissipates 3.5W through its power DIP. The junction-to-ambient thermal resistance is 36°C/W. You can now order sample quantities; production quantities will be available July 1 for $6 (1000).—***Anne Watson Swager***

Power Integrations Inc, 411 Clyde Ave, Mountain View, CA 94043. Phone (415) 960-3572. FAX (415) 940-1226.

Circle No. 730



You can design a 3W, switching power supply *that fits in a ½-in.^{3} space with one PWR-SMP3 and assorted other external components.*

Just when Power Seekers thought they had nowhere left to go...

Introducing the

IBM RISC System/6000™ family.

With the most powerful desktop workstation on earth.

No matter how big the job you're setting off to conquer, the new IBM RISC System/6000 family of POWERstations and POWERservers is for you. The desktop POWERstation 320 puts more than 7 MFLOPS and over 27 MIPS at your command—power that soars as high as 13 MFLOPS and 41 MIPS in other models.

What makes it possible is POWER Architecture—Performance Optimization With Enhanced RISC—IBM's second generation of RISC technology. It delivers up to four instructions per cycle and has the most powerful CMOS microprocessor in the business.

	MFLOPS	MIPS	SPECmark™
POWERstation 320†	7.4	27.5	22.3
DECstation™ 3100‡	1.6	14.3	10.1
SPARCstation™ 1‡	1.4	12.5	8.4

†MFLOPS are the results of the double-precision, all FORTRAN Linpack test 100 x 100 array suite. The Dhrystone Version 1.1 test results are used to compute RISC System/ 6000 Integer MIPS values where 1,757 Dhrystones/second is 1 MIPS (VAX 11/780). SPECmark is a geometric mean of ten benchmark tests.

‡Performance data are based on published benchmark information.

Micro Channel™ makes bottlenecks ancient history. All RISC System/6000 models feature a new implementation of the IBM Micro Channel bus with I/O throughput of up to 40 megabytes per second. And the Micro Channel Architecture can accommodate a doubling or even quadrupling of this data transfer capacity, making traditional, nonexpandable architectures seem primitive by comparison.

Solid support for all UNIX® applications. These systems are all based on the industry-standard UNIX operating system. And they'll run hundreds of applications in such diverse fields as engineering design, fluid dynamics, molecular modeling, securities trading, technical publishing and geophysical modeling, plus a wide selection of commercial applications.

A brave new world of 3D graphics. All our POWERstations are built to deliver high-speed, high-resolution graphics. Our 3D processors offer an almost unimaginable palette of 16 million colors. And our new Supergraphics POWERstation 730 gives you 3D graphics capabilities that are really out of this world, performing nearly one million 3D vector transformations per second.

AIX™ brings different worlds together. Every model can come preloaded with AIX Version 3, IBM's version of the UNIX operating system. It supports major industry standards, like POSIX™ and TCP/IP, plus the programming languages C, FORTRAN, COBOL and Pascal. And AIX allows the RISC System/6000 family to fit into your installed UNIX base, as well as your IBM SAA™ environments, giving you the best of both worlds.

Supercomputer speed at a workstation price: $12,995. Our entry desktop POWERstation 320 starts at $12,995 complete.* And every member of the RISC System/6000 family comes with software service at no extra charge and a 12-month warranty.

The worldwide support of IBM. Then, of course, there's IBM service when you need it, 24 hours a day, 365 days a year. To find out more, call your IBM marketing representative or Business Partner. For literature, call 1 800 IBM-2468, ext. 225. And find out why it's the beginning of a new world for Power Seekers.

For the Power Seeker.

---

*The POWERstation 320 comes with 8MB of RAM, 120MB of disk, 19-inch grayscale display and graphics adapter, keyboard, mouse, Ethernet™ adapter, AIX operating system, user interface environment, NFS™ and hypertext documentation search and retrieval capability.

IBM

IBM is a registered trademark, and RISC System/6000, Micro Channel, AIX, and SAA are trademarks of International Business Machines Corporation. UNIX is a registered trademark of AT&T. Inc. Ethernet is a trademark of the XEROX Corporation. POSIX is a trademark of Institute of Electrical and Electronic Engineers. DECstation 3100 and VAX are trademarks of Digital Equipment Corporation. SPARCstation 1 and NFS are trademarks of Sun Microsystems. SPECmark is a trademark of Standard Performance Evaluation Corporation. HAGAR THE HORRIBLE Character(s) © 1990 King Features Syndicate, Inc. © IBM Corp. 1990 all rights reserved.

Analog
TECHNOLOGY

S/H and T/H amplifiers

Discrete S/H and T/H (track-and-hold) amplifiers remain afloat in today's sea of data-acquisition design options. Improvements in accuracy, speed, and integration continue to make S/H and T/H amps a high-performance choice for applications that require the flexibility of discrete designs.

Anne Watson Swager, Associate Editor

Several factors currently threaten the role of the discrete S/H amplifier. Many successive-approximation and subranging flash converters now integrate the sample-and-hold function and the ADC on the same substrate or in the same hybrid package. New sigma-delta converters do not require the S/H function. And many manufacturers of flash and subranging converters claim that the S/H function is no longer necessary for their "new and improved" devices. Regardless of these factors, however, discrete S/H amps are not going to disappear, nor will their performance stagnate. For performance or flexibility, there are times when you'll still need a discrete S/H amplifier.

When you do need a S/H amp, you'll appreciate the ability to buy one off the shelf. Designing a S/H amp using discrete op amps is certainly possible, but designing one that has high performance in several specifications is a very difficult task. Precision Monolithic Inc's (PMI) Steve Sockolov said it best: "Designing a S/H amp is like trying to flatten a waterbed by pushing on it in different places."

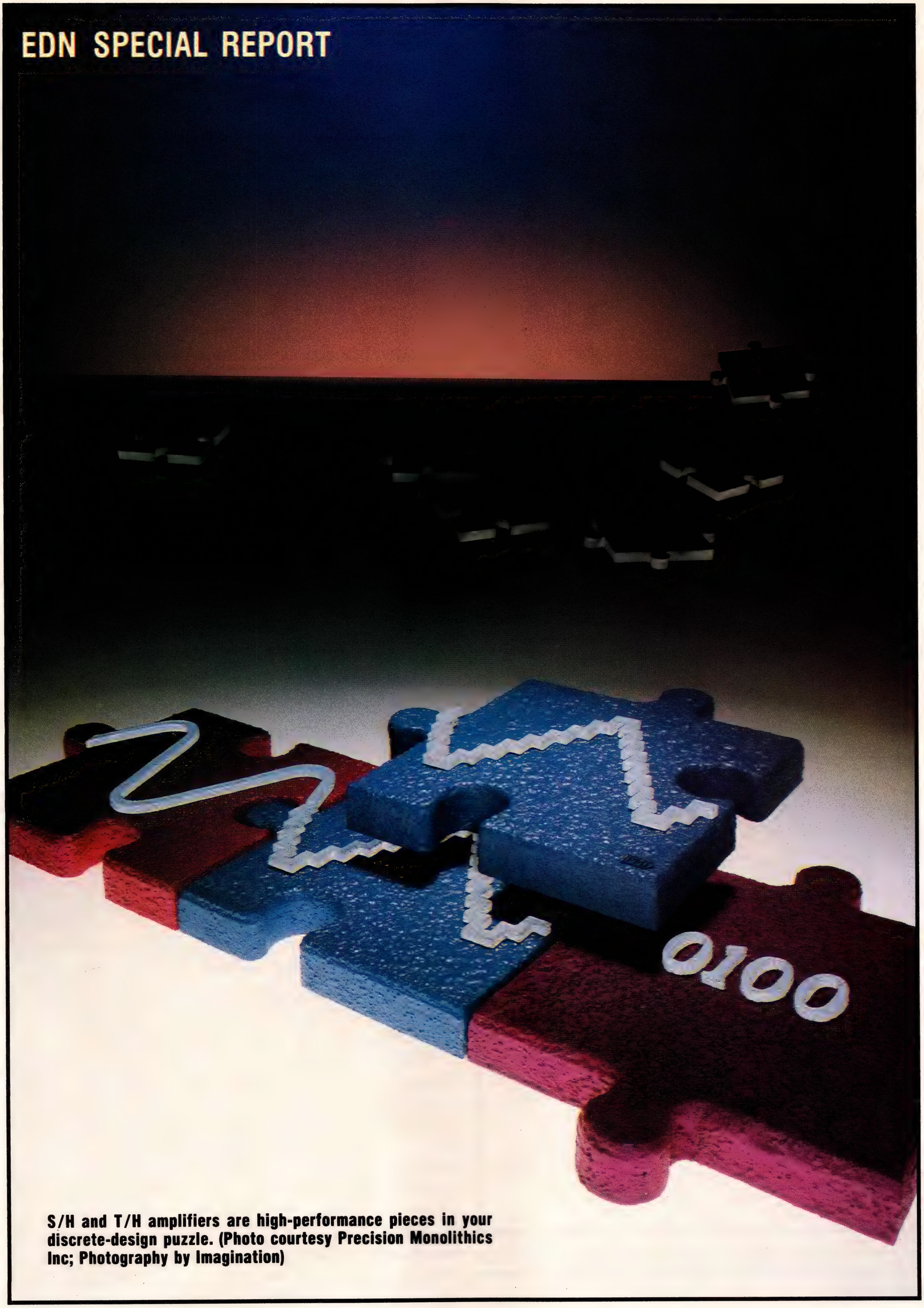
Although manufacturers introduce far fewer new S/H amps than ADCs, you now have access to devices with 25-nsec acquisition times commensurate with 12-bit ADC accuracy, true 16-bit accurate S/H amps, and a monolithic device that integrates eight multiplexed S/H amps **(Table 1)**. The trend to develop converters with built-in S/H amps actually results in new discrete S/H amps. Many manufacturers of hybrid sampling ADCs, such as Burr-Brown and Datel, often spin off the S/H amp and offer it in one package.

Of course, S/H-amp applications aren't limited to data-acquisition systems. You can use S/H amps to design peak detectors, D/A deglitchers, and other linear functions. S/H amps have also found their way into automatic test equipment, where they keep a signal stable until a particular node's test is complete.

S/H and T/H amps are among the most challenging linear components to design and specify. To use them successfully you'll need to familiarize yourself with their terminology and specifications. The first term to get straight is the name of the parts themselves. Although S/H and T/H amps have identical uses—keeping a signal stable until further signal processing can occur—the two devices are theoretically different. The main difference is that a S/H amp spends most of its time in the hold mode irrespective of the input, whereas a T/H device spends most of its time in the track mode, following the input.

These pure definitions may have once made a difference. Unfortunately, because the industry has used the two terms loosely, they've lost any specific meaning. Most so-called S/H amps are really T/H devices. The sampling rate also blurs the distinction between device types. According to Analog Devices, the terms "track and hold" and "sample and hold" lose their distinction for data-acquisition systems that operate at rates greater than 1 MHz **(Ref 1)**. From here on, the

EDN SPECIAL REPORT



S/H and T/H amplifiers are high-performance pieces in your discrete-design puzzle. (Photo courtesy Precision Monolithics Inc; Photography by Imagination)

Designing a S/H amplifier is like trying to flatten a waterbed by pushing on it in various places.

term "sample and hold" applies to both S/H and T/H amps.

Approximately 80 percent of the S/H amps sold are used in data-acquisition applications, so the most appropriate way to discuss S/H amps is in the context of those systems. However, discussing the performance of these amps and how you use them doesn't make much sense unless you actually need one. Although the new oversampling architectures don't require S/H amps—these architectures essentially do a 1-bit conversion followed by a massive amount of digital filtering—most other familiar ADC architectures require you to decide whether or not you'll need a S/H amp. That decision is a little cloudy, especially because converter performance continues to improve. Flash converters now have much more manageable input capacitances, and their comparator banks have improved characteristics. Because of this confusion, you may design a system without a S/H amp only to have to go to the trouble of adding one later.

Three closely related issues determine whether you'll need a S/H amp: the type of converter you're using; the speed of the signal you want to digitize; and the accuracy you want to achieve. If you want to digitize at Nyquist rates, think seriously about using a S/H amp, regardless of the converter type. For any signal frequencies except dc, successive-approximation converters, by virtue of their conversion architecture, always require S/H amps. The following basic equations easily reveal the limitations of successive-approximation converters. The maximum rate of change of a sinusoidal signal, $V(t) = A\sin\omega t$, is

$$dV/dt_{MAX} = A\omega = A2\pi f,$$

where A is the input-voltage range.

For the input to change by no more than ½ LSB, then the maximum rate of change is

$$dV/dt_{MAX} = \tfrac{1}{2}\ \text{LSB (V)/ADC's conversion time (sec)}.$$

Thus,

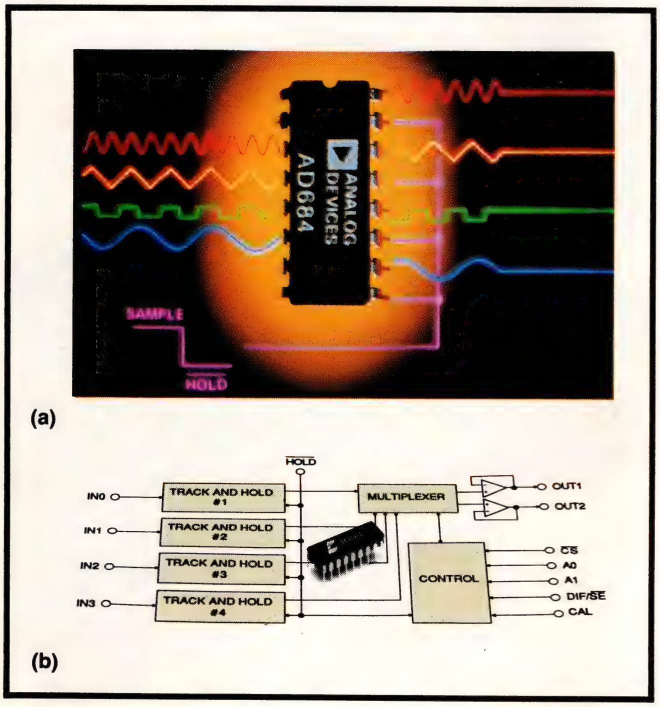
$$\tfrac{1}{2}\ \text{LSB/conversion time} = A2\pi f.$$

You can use this equation to solve for the maximum frequency, f, that the ADC can convert to ±½-LSB accuracy. You can also use the equation to determine f for other accuracy levels. For example, if you're using a 12-bit, 1-µsec converter with a 10V input range, ±½-LSB corresponds to 1.2 mV. For such a converter,

$$f = 1.2\ \text{mV}/(1\ \mu\text{sec} \times 10 \times 2\pi) = 19.1\ \text{Hz}.$$

This hypothetical converter can only convert signals to 19.1 Hz to ½-LSB accuracy. Thus if you're using a successive-approximation converter and you want to convert anything other than very slow signals to a high degree of accuracy, you'll need a S/H amp.

Whether you need a S/H amp in front of a flash converter is less straightforward. Technically, a flash converter's architecture takes an instantaneous sample of the input. However, each comparator doesn't sample at the same time; the ADC's aperture jitter can degrade the accuracy of the conversion, especially at high sample rates. Generally, one word solves the S/H debate: Nyquist. According to Allen Hansford of Comlinear Corp, "S/H or T/H amps will do absolutely no good at low sampling rates." If you're using a converter with a very low sampling rate compared with its maximum capability—a 5:1 ratio between sampling



Quad S/H packages such as these from Analog Devices and Crystal Semiconductor feature four completely independent S/H amps and internal hold capacitors.

Dynamic specifications appear more regularly on S/H-amplifier data sheets. S/N ratio is critical to many signal-processing applications. (Photo courtesy Analogic Corp)

rate and the highest input frequency, for example—you're probably right to assume that a S/H amp would be overkill.

However, if you're running a converter anywhere close to its maximum sampling rate—digitizing a signal at the Nyquist limit—and you want to come close to the maximum attainable accuracy of ½ LSB, you're going to need a S/H amp. There are a few exceptions to this rule, but don't let any manufacturer easily sway you. Various converters' bandwidths can be, surprisingly, higher than one half of the sampling rate. These higher-than-Nyquist converters are among the group that may truly not require a S/H amp for near-Nyquist sampling.

The purpose of the S/H amp is to reduce the aperture error of the flash ADC. Just as a successive-approximation converter can't accurately convert a signal whose input changes by more than ±½ LSB during the conversion time, a flash ADC can't accurately convert a signal that changes by more than ±½ LSB during its aperture-jitter time. The ratio of the ADC's aperture jitter and the S/H amp's aperture jitter is a rough estimate of the improvement you can achieve by using a S/H amp with a flash converter. This improvement ratio applies only if the converter doesn't have any internal slew-rate limitations. Some flash converters have internal bottlenecks that a fast S/H amp can do nothing about.

Once you determine that you do indeed need a S/H amp in your system, your next step, choosing just the right S/H amp, is no easy task (**Refs 2, 3**). In addition to the variety of discrete S/H amps available, there are various other ways you can obtain the sample-and-hold function.

Sampling converter vs discrete components

Over the last few years the number of sampling ADCs—converters that include a S/H amp internally—has proliferated. Sampling ADCs first appeared exclusively in hybrid form, but now monolithic devices are available. Few engineers or manufacturers dispute the advantages of the sampling package for certain applications. Manufacturers of these sampling ADCs match the characteristics of the S/H amp and A/D converter, and more importantly, dynamically characterize the S/H-ADC pair.

However, if current sampling packages can't meet your accuracy, speed, or cost requirements, you'll need to use a discrete S/H amp. Many hybrid sampling ADCs currently feature 12 bits of accuracy and a 1-MHz sampling rate. A few sampling hybrids based on the 2-pass flash-conversion technique have sampling rates in the 10-MHz range. Twelve-bit monolithic sampling A/Ds, such as those from Analog Devices, Burr-Brown, and Crystal Semiconductor, have signal bandwidths around 100 kHz. Most of these monolithic sampling devices have an "inherent" sampling function because they use either sampled-data comparators or a charge-redistribution technique.

In addition to requiring a particular accuracy and speed, numerous data-acquisition applications require the flexibility of separate sample-and-hold functions. Manufacturers claim that a sampling package is a cheaper solution for single-channel or multiplexed systems. However, simultaneous sampling, or cascading fast-acquisition and long-hold-time S/H amps, call for a discrete approach. These systems require that each S/H amp's characteristics closely match. By integrating

Text continued on pg 78.

Table 1—Distinguishing features of representative S/H and T/H amplifiers*

Manufacturer	Part number	Accuracy (bits)	Acquisition time	Architecture	Distinguishing features	Input range (V)	Power (W)	Package	Price (100s)
Analog Devices	AD386	16	4.1 μsec (10V step to 0.00076%)	closed loop	True 16-bit T/H amplifier over extended industrial temperature range.	±10	0.435	24-pin hybrid DIP	$79
	AD684	12	1 μsec (10V step to 0.01%)	NA	Four independently controllable S/H amps per package. Self-correcting architecture.	±5	0.53	16-pin DIP	$23.50
	AD1154	16	8 μsec (20V step to 0.00076%)	closed loop	Low-cost, true 16-bit T/H amp.	±10	0.3 (typ)	14-pin hybrid DIP	$49.50
Analogic Corp	AH20016	16	400 nsec (10V step to 0.0015%)	closed loop	Very high combination of speed and precision.	±10	1.24	24-pin hybrid DDIP	$185
	SHA2200	14	250 nsec (10V step to 0.006%)	closed loop	High combination of speed and precision. Nonlinearity ±0.003% max.	±5	1.1	24-pin hybrid DDIP	$130
	SHA2410	16	2.5 μsec (10V step to 0.0015%)	open loop	Combines high accuracy with low noise.	±5	0.54	14-pin hybrid DDIP	$62.25
Burr-Brown Corp	SHC5320	12	1.5 μsec (10V step to 0.01%)	closed loop	Low-cost monolithic device with moderate accuracy and speed.	±10	0.33	14-pin DIP	$8.30
	SHC600	12 and 14	50 nsec (2.5V step to 0.02%)	closed loop	High speed and high accuracy for 12-bit systems. 100-MHz sample rate, 350V/μsec slew rate. Used in ADC603.	±2	1.3 (typ)	24-pin DIP	$235
	SHC601	12	22 nsec (typ) (2.5V step to 0.02%)	open loop	Combines high input bandwidth with low aperture uncertainty.	±2	1.25	24-pin DIP	$190
	SHC76	14	6 μsec (20V step to 0.003%)	closed loop	Moderate speed, high accuracy, companion to company's 14-bit converters.	±10	0.3	14-lead metal can	$58.50
	SHC702	14 and 16	600 nsec (typ) (10V step to 0.0015%)	closed loop	Low harmonic distortion and high S/N ratio, characterized performance when coupled with company's ADC702.	±11	0.95	24-pin metal package	$168
Comlinear Corp	CLC940	10	18 nsec (2V step to 0.1%)	open loop	High speed to 10-bit accuracy. 140-MHz input bandwidth, 440V/μsec slew rate.	±2.2	1.8	24-pin hybrid DIP	$196
	CLC942	12	25 nsec (2V step to 0.01%)	open loop	Very high speed to 12-bit accuracy. 50-MHz bandwidth, 250V/μsec slew rate.	±2.2	0.98	24-pin hybrid DIP	$139
Crystal Semiconductor	CS3112	12	1 μsec (6V step to 0.01%)	closed loop	Moderate speed, low cost, self-calibrating circuitry maintains performance over time and temperature.	±3	0.2	14-pin DIP 20-pin PLCC	$12
	CS31412	12	1 μsec (6V step to 0.01%)	closed loop	Four S/H amps and analog multiplexers per package, self-calibrating circuitry maintains performance over time and temperature.	±3	0.45	18-pin DIP	$36
Datel Inc	SHM-361	10	12 nsec (2V step to 0.15%)	open loop	High speed to 10-bit accuracy, low cost.	±3	0.78	24-pin DIP	$11.25
	SHM-30	12	500 nsec (10V step to 0.01%)	closed loop	Good combination of speed and low droop rate.	±10	0.75	14-pin DIP	$14.95
	SHM-42	12	50 nsec (2V step to 0.01%)	open loop	High speed to 12-bit accuracy.	±2	0.75	24-pin hybrid DIP	$139
	SHM-43	12	25 nsec (2V step to 0.01%)	open loop	Very high speed to 12-bit accuracy in small package, low power dissipation.	±2	0.5	14-pin hybrid DIP	$149
	SHM-945	16	500 nsec (20V step to 0.001%)	closed loop	High combination of speed and accuracy. Differential inputs enable rejection of common-mode signals.	±5 or ±10	NS	24-pin hybrid DDIP	$149
Harris Semiconductor	HA-2420/25	12	6 μsec (10V step to 0.01%)	closed loop	2.5-MHz gain-bandwidth product. Requires external hold capacitor.	±10	0.165 at 25° C	14-pin DIP, 20-pad LCC	$4.15
	HA-5320	12	1.5 μsec (10V step to 0.01%)	closed loop	Low-cost monolithic with precision input characteristics, pedestal-null capability.	±10	0.39 at 125° C	14-pin DIP, 20-pad LCC	$10.03
	HA-5330	12	500 nsec (typ) (10V step to 0.01%)	closed loop	Good combination of high speed, low cost, and low droop rate. Differential inputs.	±10	0.75 at 125° C	14-pin DIP, 20-pad LCC	$15.65
	HA-5340	12	700 nsec (typ) (10V step to 0.01%)	closed loop	Low hold-mode-distortion specs in low-cost monolithic package.	±10	0.75	14-pin DIP	$18.38
ILC Data Device Corp	TH-8530	8	15 nsec (no load) (2V step to 0.1%)	open loop	High speed to 8-bit accuracy, wide operating temperature range.	±1	1.9	24-pin hybrid DDIP	$325
	TH-05203	12	200 nsec (10V to 0.01%)	closed loop	High speed to 12-bit accuracy, low linearity error, wide operating temperature range. HTC-0300A and TP4860 compatible.	±11.5	0.915	24-pin hybrid DDIP	$190

Manufacturer	Part number	Accuracy (bits)	Acquisition time	Architecture	Distinguishing features	Input range (V)	Power (W)	Package	Price (100s)
Micro Networks	MN373	14 to 16	10 μsec (10V step to 0.003%)	closed loop	Low cost with moderate speed to 14-bit accuracy.	±10	0.39	14-pin hybrid DIP	$39
	MN374	14 to 16	4 μsec (20V step to 0.003%)	closed loop	Moderate speed to 14-bit accuracy. Pin and function compatible with SHC76.	±10	0.495	14-pin hybrid DIP	$50
	MN376	12	200 nsec (10V step to 0.01%)	closed loop	High speed to 12-bit accuracy.	±10	0.875	24-pin hybrid DIP	$137
	MN379	7 to 9	30 nsec (5V step to 1%)	open loop	High speed, flash-converter compatible. Drives capacitive loads of 500 pF.	±2.5	2.025	24-pin hybrid DIP	$149
	MNHT-0010	10	22 nsec (2V step to 0.1%)	open loop	Very high speed to 10-bit accuracy. −78 dBc of harmonic distortion.	±2	1.5	24-pin hybrid DDIP	$224
	MNHT-0025	10	22 nsec (2V step to 0.1%)	open loop	High speed to 10-bit accuracy. 30-MHz full-power bandwidth, high input impedance.	±2	2	24-pin hybrid DDIP	$204
National Semiconductor	LF398	12	4 μsec (10V step to 0.1%) (C=1000 pF)	closed loop	Extremely low-cost monolithic, industry-standard device. Requires external hold capacitor.	±V_{cc}	0.195	8-pin DIP	$2.19
	LHA4860	12	200 nsec (10V step to 0.01%)	closed loop	High speed and bandwidth to 12-bit accuracy, includes bypass capacitors, compatible with 4960, among others.	±11.5	0.875	24-pin metal package	$67
Precision Monolithics Inc	SMP-04	8 to 12	1 μsec (13V step to 0.1%)	closed loop	Four S/H amps and precision buffer amps per package. 12-bit linearity. 5 to 18V supply operation.	varies with V_{cc}	0.09 (V_{cc} = 5V)	16-pin DIP, 16-pin SOIC	$3.90
	SMP-08	10	5 μsec (10V step to 0.01%)	open loop	Eight S/H amps per package with multiplexing capability to one voltage source. 5 to 18V supply operation.	varies with V_{cc}	0.04 (V_{cc} = 5V)	16-pin DIP, 16-pin SOIC	$3.50
	SMP-10/11	12	5 μsec (typ) (10V step to 0.01%)	closed loop	Moderate speed, low cost. Requires external hold capacitor.	±10	0.18	14-pin DIP	$9.50/ $2.25
Signetics	NE5060	12	1.25 μsec (10V step to 0.01%)	closed loop	Functional equivalent of HA5320 and SMP11.	±10	0.42	14-pin DIP	$7.25
	NE5537	10	4 μsec (typ) (10V step to 0.1%) (CH=1000 pF)	closed loop	Pin compatible with the LF198, but has a lower droop rate and higher output-drive capability. Requires external hold capacitor.	±11.5	0.27	8-pin DIP, 14-pin SO	$1.05
Sipex Corp	HS9714/16	14/16	5 μsec (typ) (20V step to 0.0008%)	closed loop	High accuracy with moderate speed. Low droop rate due to dielectric absorption compensation.	±10	0.5	14-pin hybrid DDIP	$79
	SP9730	12	120 nsec (5V step to 0.01%)	closed loop	High speed to 12-bit accuracy.	±10	1	24-pin hybrid DDIP	$136
	SP9760	14 and 16	350 nsec (typ) (20V step to 0.0015%)	closed loop	Very high combination of speed and precision.	±10	0.825	24-pin hybrid DDIP	$199
Sony Corp	CXA1008/9	9	12/20 nsec (1.2V to 0.2%)	closed loop	Very high speed to 9-bit accuracy, low-cost monolithic. Internal buffer amp and −2V reference.	±3	0.68/ 0.42 typ	24-pin DIP	$15.30/ $8.90
Teledyne Components	4860	12	200 nsec (10V step to 0.01%)	closed loop	High speed to 12-bit accuracy.	±11.5	0.95	24-pin DIP	$99
	4867	12	100 nsec (10V step to 0.01%)	closed loop	High speed to 12-bit accuracy. Full temp versions available.	±11.5	1.2	24-pin metal DIP	$157
TRW LSI Products	THC4940	10	12 nsec (2V step to 1%)	open loop	Very high speed to 10-bit accuracy. 150-MHz small-signal bandwidth.	±2.2	1.8	24-pin DIP	$196
Vanguard Semiconductor	VN1025	10	25 nsec (1V step to 0.1%)	closed loop	Very high speed to 10-bit accuracy.	±3	0.93	24-pin metal DIP, 20-pad LCC, 18-pin cerdip, 24-pin SOIC	$109

***Notes:** Maximum specifications quoted unless otherwise specified.
All S/H amps have internal capacitors unless otherwise specified.
Prices quoted are for commercial temperature ranges.
DDIP = double-wide DIP
PLCC = plastic leaded chip carrier
NS = not specified

> **The trend to develop A/D converters with built-in sampling often results in new discrete-S/H-amplifier introductions.**

multiple S/H amps in one package, manufacturers are able to more tightly control each S/H amp. **Table 1** includes a number of quad devices from Analog Devices, Crystal Semiconductor, and PMI. Also, PMI recently introduced an 8-channel, multiplexed sample-and-hold amp. The device multiplexes one voltage source, such as a DAC output, to eight independent outputs. It integrates functions that previously required a CMOS multiplexer and assorted external components.

Knowing a little bit about the internal architectures of S/H amps will help you understand the origin of various errors and thus various specifications. The basic components of a S/H amp are a switch, a hold capacitor, and an output amp (**Fig 1a**). The two most common architectures are closed loop and open loop (**Figs 1b, 1c, 1d**). The output amplifier of a closed-loop device usually has either a follower or integrator configuration. According to Analog Devices' nonlinear handbook, closed-loop S/H amps exploit the accuracy, low

Stellar Performers

Name	Also known as...	Definition	Accuracy range (bits)	Specified performance	High performers	Manufacturer
Acquisition time	Hold-to-sample time, hold-to-track time	Time between application of the track or sample command and the point when the hold capacitor or output settles to a specified percentage of the input value.	8 to 10	12 nsec (2V step) 12 nsec (1.2V step) 12 nsec (2V step) 15 nsec (2V step) 25 nsec (1V step)	SHM-361 CXA1U08 THC4940 TH-8530 VN1025	Datel Sony TRW ILC DDC Vanguard
			12	22 nsec (2.5V step) 25 nsec (2V step) 25 nsec (2V step)	SHC601 CLC942 SHM-43	Burr-Brown Comlinear Datel
			14 to 16	250 nsec (10V step) 350 nsec (20V step) 400 nsec (10V step) 500 nsec (20V step)	SHA2200 SP9760 AH20016 SHM-945	Analogic Sipex Analogic Datel
Hold-mode settling time	Track-to-hold settling time, sample-to-hold settling time	Time required for the output to settle in the hold mode within certain limits following the transition from the track mode.	8 to 10	14 nsec 14 nsec 14 nsec 15 nsec 15 nsec	CLC940 MNHT-0010 THC4940 MN379 TH-8530	Comlinear Micro Networks TRW Micro Networks ILC DDC
			12	7 nsec 14 nsec 15 nsec	CLC942 SHC601 SHM-43	Comlinear Burr-Brown Datel
			14 to 16	100 nsec 100 nsec 150 nsec 150 nsec	SHA2200 SHM-945 AH20016 SP9760	Analogic Datel Analogic Sipex
Aperture time	Aperture delay, aperture-time delay, gate delay	Time between application of the hold command and the instant the switch opens and thus the instant the output stops tracking the input.	8 to 10	1 nsec 2 nsec 4 nsec 5 nsec	MNHT-0010 VN1025 THC4940 TH-8530	Micro Networks Vanguard TRW ILC DDC
			12	4 nsec 5 nsec 6 nsec 6 nsec	CLC942 SHM-42 LHA4860 SP9730	Comlinear Datel National Sipex
			14 to 16	6 nsec 10 nsec 12 nsec	SHM-945 HS99714/16 AD386	Datel Sipex Analog Devices
Aperture jitter	Aperture uncertainty	Fluctuations in the aperture time as a result of noise, slew rate, the amplitude of the gating circuit, and aging and temperature effects.	8 to 10	1.4 psec 1.4 psec 2 psec rms 2 psec rms	CLC940 THC4940 MN379 VN1025	Comlinear TRW Micro Networks Vanguard

drift, and gain flexibility available with op amps. Open-loop designs take advantage of the high-speed characteristics of a unity-gain buffer amplifier.

Open-loop architectures generally lead to faster acquisition times. Closed-loop architectures slow the response but add stability. Thus, closed-loop designs have better static characteristics. As manufacturers improve S/H-amp performance, they continue to add more internal components that compensate for certain limitations of each architectural type. Therefore, you shouldn't generalize about performance from the device's architecture alone.

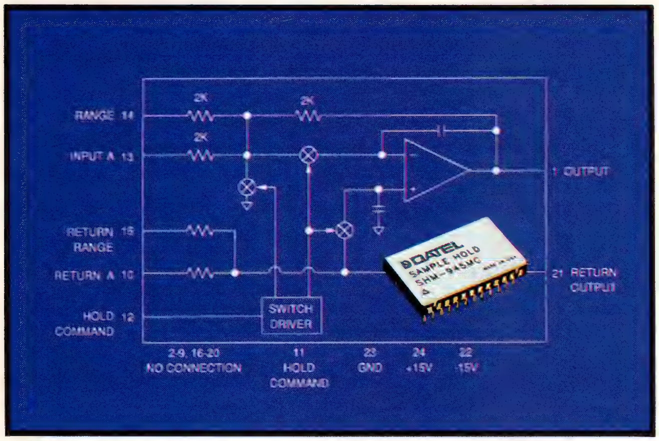
You can usually determine if a S/H amp suits your application from the device's specifications—regardless of its internal architecture. However, S/H specifications can be confusing. To put each spec into perspective, consider where in the sampling process various errors can arise **(Fig 2)**.

The various names and definitions that manufacturers use further compound the difficulty of interpreting

Name	Also known as...	Definition	Accuracy range (bits)	Specified performance	High performers	Manufacturer
Aperture jitter (continued)			12	0.9 psec 1 psec	SHC-601 SHM-43	Burr-Brown Datel
			14 to 16	5 psec rms (typ) 10 psec rms (typ) 10 psec rms (typ)	SHC600 AH20016 SHA2200	Burr-Brown Analogic Analogic
Droop rate	Hold-mode droop	Rate of change of the output while in the hold mode.	8 to 10	0.01 μV/μsec 0.02 μV/μsec 0.05 μV/μsec	SHM-361 VN1025 SMP-04	Datel Vanguard PMI
			12	0.01 μV/μsec 0.01 μV/μsec 0.02 μV/μsec 0.03 μV/μsec 0.6 μV/μsec	SHM-30 HA-5330 SMP-10 LF398 CS3112/31412	Datel Harris PMI National Crystal
			14 to 16	0.02 μV/μsec 0.1 μV/μsec 0.1 μV/μsec 0.1 μV/μsec 0.25 μV/μsec	HS9714/16 AD386 AD1154 SHC-76 MN373	Sipex Analog Devices Analog Devices Burr-Brown Micro Networks
Feedthrough	Hold-mode feedthrough	Amount of input coupled to the output while in the hold mode.	8 to 10	−74 dB (2V p–p, 20 MHz) −70 dB (2V p–p, 20 MHz) −70 dB (2V p–p, 1 MHz)	CLC940 THC4940 MNHT-0025	Comlinear TRW Micro Networks
			12	−90 dB (5V p–p, 100 kHz) −88 dB (10V step) −84 dB (20 V p–p, 100 kHz) −78 dB (2V p–p, 20 MHz)	AD684 SHM-30 MN376 CLC942	Analog Devices Datel Micro Networks Comlinear
			14 to 16	−100 dB (20V p–p, 250 kHz) −100 dB (10V p–p, 25 kHz) −98 dB (10V p–p, 500 kHz) −98 dB (20V p–p, 20 kHz) −96 dB (10V step)	AH20016 SHA2410 SHA2200 HS9714/16 SHM-945	Analogic Analogic Analogic Sipex Datel
Pedestal voltage	Track-to-hold offset, sample-to-hold offset, hold step	A step in the output voltage that occurs as the circuit goes into the hold mode.	8 to 10	1 mV 5 mV 5 mV	VN1025 CLC940 THC4940	Vanguard Comlinear TRW
			12	0.25 mV (typ) 0.5 mV (typ) 1 mV	CS31412 HA5330 SHC5320	Crystal Harris Burr-Brown
			14 to 16	1 mV 1 mV 1.5 mV	AH20016 SP9760 AD386	Analogic Sipex Analog Devices

Note: Based on specifications supplied by the manufacturers (some specs are maximum and some are typical), these numbers are the best estimate of the highest performance currently available.

S/H and T/H amplifiers are truly some of the most interesting linear components, and their specifications are anything but trivial.



Block diagrams of S/H amplifiers are no longer as simple as a switch, amplifier, and hold capacitor. (Photo courtesy Datel Inc)

the specs. **Table 2** provides the various synonyms, standard definitions, and various parts that have high performance in each category. The entries represent the highest performance attainable in each specification. Unfortunately, no one part features state-of-the-art performance in each category. Ultimately, you choose a S/H amp based on all of its specifications.

Speed and accuracy, for example, are both loaded terms that require you to consider many different specs. **Table 1**'s accuracy column gives you an idea of the ADC's or system's accuracy in terms of bits that each particular S/H amp is compatible with. However, describing or specifying a S/H amp's accuracy isn't as simple as stating one single number.

S/H-amp specs are a prime example of the need to read the fine print. Many of the specs involve myriad test conditions. Be suspicious of product announcements that don't quote speed and accuracy together. Acquisition time dominates a S/H amp's speed, but both acquisition and hold-mode settling time will determine the maximum operational speed of the device. Some manufacturers, such as Datel and Analog Devices, define this time as the time required for the hold capacitor to charge to a full-scale voltage and to remain within a specified error band around its final value.

Other manufacturers, such as Micro Networks, define acquisition time as the total elapsed time between the application of the sample or track command (usually defined as the midpoint in the digital track-and-hold command signal) and the point at which the analog output enters and remains within a specified error band around its final value. Most manufacturers specify acquisition time starting from the 50% point of the sample/track command line, but a few subtract the amount of time it takes for the output to begin slewing to the new input value. This time, called acquisition-delay time, is not always specified.

Comparing different S/H amps' acquisition times not only requires that you understand each manufacturer's definition, but also that you know the final error band and input-voltage step. Many manufacturers perform acquisition tests under worst-case conditions; the amp is holding at minus full-scale, and the new input is plus full scale. Under these worst-case conditions, the amp has to slew over its entire input range and settle to the input. Different S/H amps have different input ranges. Thus, there isn't any standard test.

Hold-mode settling time is the amount of time it takes the output amplifier to settle when you switch to hold mode. The act of opening the sample switch

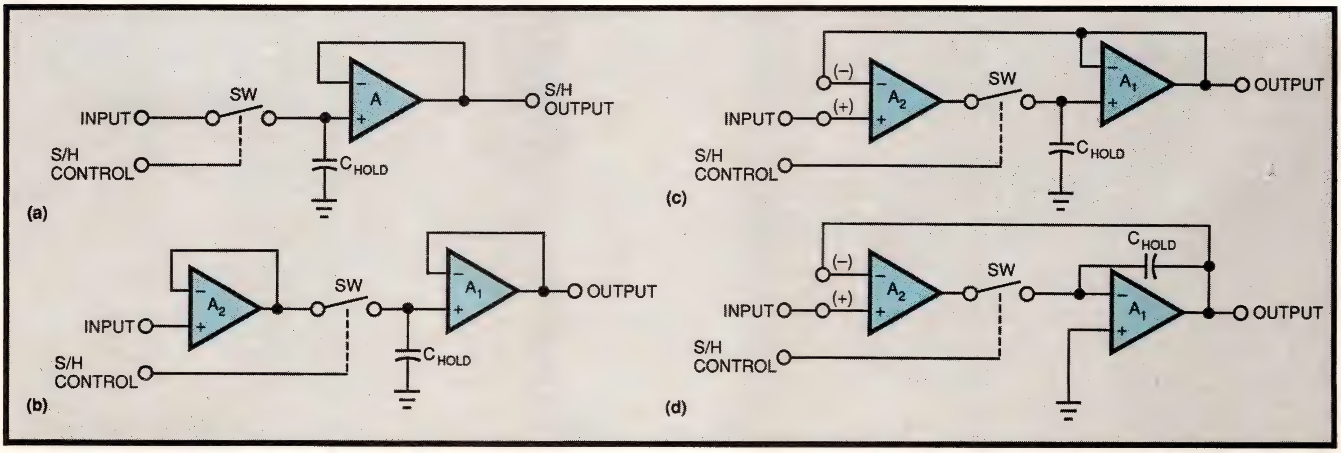


Fig 1—The most basic S/H amplifier consists of a switch, a hold capacitor, and an output amplifier (a). Today's S/H amps usually incorporate open-loop architectures (b) or closed-loop architectures with a follower output (c) or integrator output (d) to reduce the deleterious effects of the basic components.

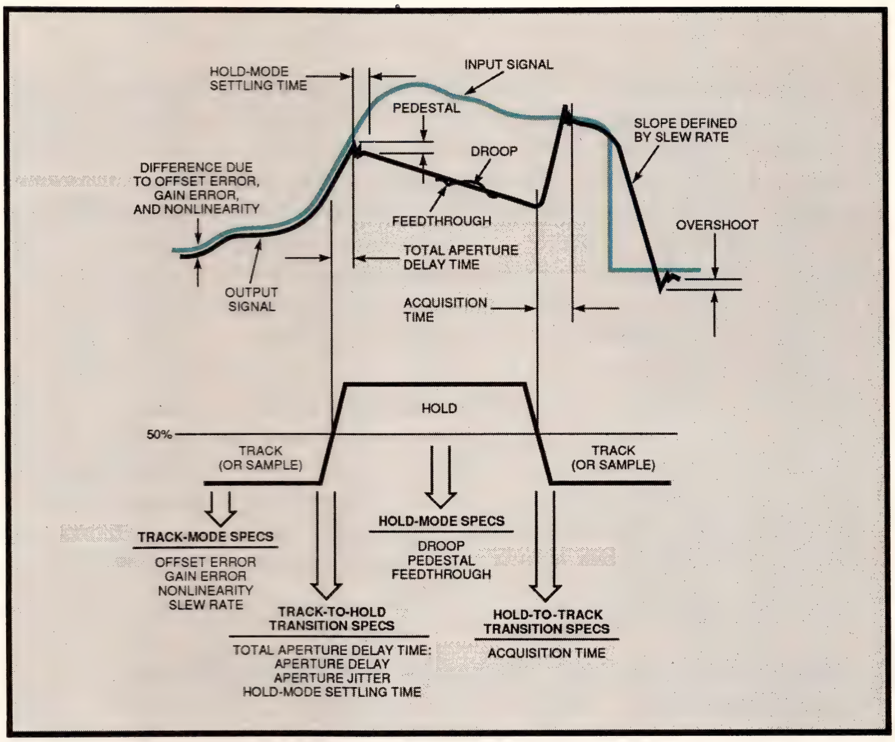


Fig 2—You can associate S/H-amplifier specifications with the portion of the T/H command pulse where they arise. The two transition periods cause the timing restrictions. Static and accuracy errors stem from both track and hold interval characteristics.

introduces output transients; you must wait for these to settle out to achieve an accurate conversion. Opening the switch can also cause thermal tails. According to Comlinear's Hansford, the act of switching causes overshoots and undershoots, which in turn cause instability due to heating effects. The resultant thermal tails can cause as much as a 0.01% shift in the output voltage.

The hold-mode settling-time spec also has important test criteria: the final accuracy that the output settles to and the load conditions. Manufacturers usually quote the final accuracy in mV; ±1 mV is equivalent to ±½ LSB in a 12-bit S/H amp with a 10V full-scale input range. Look for typical load conditions in the range of $R_L = 2\ k\Omega$ and $C_L = 50\ pF$.

By taking the inverse of the sum of the acquisition time and hold-mode settling time, you can calculate a S/H amp's maximum sampling rate. This number is the highest rate at which the S/H amp can sample the input. However, focusing exclusively on this number is limiting. Remember that the S/H is only part of the overall conversion process. The following equation yields the overall effective throughput of your system:

$$\text{Throughput} = \frac{1}{\substack{\text{acquisition}\\ \text{time}} + \substack{\text{hold-mode}\\ \text{settling}\\ \text{time}} + \substack{\text{start-}\\ \text{convert}\\ \text{pulse}} + \substack{\text{delays/}\\ \text{overhead}} + \substack{\text{conversion}\\ \text{time}}}.$$

If your S/H amplifier needs to sample sinusoidal signals—a periodic-sampling application—aperture delay and aperture jitter are important timing specifications to consider **(Ref 3)**. Aperture delay isn't too difficult to deal with; you can compensate for it by modifying the S/H amp and converter timing of your system. Aperture jitter, however, limits the maximum signal frequency that the amp can effectively sample and hold. Again, a familiar equation helps you determine the maximum frequency of the S/H:

$$dV/dt_{MAX} = 2\pi fA.$$

To maintain the desired accuracy, the S/H amp's input can't change by more than the desired number of LSBs during the aperture-jitter interval. Thus you can equate the accuracy in volts to the jitter spec seconds as follows:

$$\text{desired accuracy/S/H amp's aperture jitter} = 2\pi fA$$

By solving for f, you obtain the maximum frequency possible through the S/H amplifier. This number is based on the aperture jitter only. You still need to check the slew-rate spec of the S/H amp to be sure that it doesn't limit the maximum frequency further.

Other specs related to accuracy in the hold mode are

Interpreting S/H-amplifier specifications requires that you read between the lines and take note of definitions.

the S/H amp's pedestal offset, droop rate, and the amount of feedthrough. Pedestal offset is a fixed hold-mode error that, along with gain and offset errors, determines your system's overall accuracy. The size and quality of the hold capacitor determines the droop rate. All but a few of **Table 1**'s amps have internal capacitors. The advantage of internal capacitors is that you don't have to worry about choosing the capacitor type or about the effects of the external connection.

However, some devices allow you to add external capacitance so that you can improve hold-mode characteristics at the expense of acquisition time. If you do so, you must be very concerned with the type of capacitor you use and the layout of the S/H amp and its external capacitor (**Ref 4**). Any leakage from the internal capacitor's node to the surrounding board or components will destroy the droop rate. Regardless of whether a S/H amp has an internal capacitor or you add one externally, the droop rate is extremely sensitive to temperature. Many manufacturers supply droop-rate specs at high temperatures, in addition to the standard 25°C spec. If your system will experience extreme temperature fluctuations, be sure to check the droop rate at these temperatures.

The amount of feedthrough manufacturers specify also relies on some test conditions, namely, the amplitude and frequency of the input-test voltage. Feedthrough arises mainly as a result of capacitance across the sampling switch. This spec relates to the maximum S/N ratio you can expect to get out of your conversion system. Thus, the feedthrough is related to the accuracy of the S/H amp. Note from **Table 2**

Manufacturers of S/H and T/H amplifiers

For more information on S/H and T/H amplifiers such as those described in this article, circle the appropriate numbers on the Information Retrieval Service card or use EDN's Express Request service. When you contact any of the following manufacturers directly, please let them know you saw their products in EDN.

Analog Devices
One Technology Way
Norwood, MA 02062
(617) 329-4700
FAX (617) 329-8703
Circle No. 650

Analogic Corp
360 Audubon Rd
Wakefield, MA 01880
(508) 977-3000
FAX (617) 245-1274
Circle No. 651

Burr-Brown Corp
Box 11400
Tucson, AZ 85734
(602) 746-1111
FAX (602) 889-1510
Circle No. 652

Comlinear Corp
4800 Wheaton Dr
Fort Collins, CO 80525
(303) 226-0500
Circle No. 653

Crystal Semiconductor Corp
Box 17847
Austin, TX 78744
(800) 888-5016
FAX (512) 445-7581
Circle No. 654

Datel Inc
11 Cabot Blvd
Mansfield, MA 02048
(508) 339-3000
FAX (508) 339-6356
Circle No. 655

Harris Semiconductor
Box 883
Melbourne, FL 32902
(407) 724-7000
FAX (407) 729-5691
Circle No. 656

ILC Data Device Corp
105 Wilbur Pl
Bohemia, NY 11716
(800) 332-1772
FAX (516) 567-7358
Circle No. 657

Micro Networks
324 Clark St
Worcester, MA 01606
(508) 852-5400
FAX (508) 853-8296
Circle No. 658

National Semiconductor
Box 58090
Santa Clara, CA 95052
(408) 721-5000
Circle No. 659

Precision Monolithics Inc
Box 58020
Santa Clara, CA 95052
(408) 727-9222
FAX (408) 727-1550
Circle No. 660

Signetics Co
811 E Arques Ave
Sunnyvale, CA 94088
(408) 991-2000
Circle No. 661

Sipex Corp
6 Fortune Dr
Billerica, MA 01821
(508) 663-9691
FAX (508) 670-9001
Circle No. 662

Sony Corp of America
10833 Valley View St
Cypress, CA 90630
(714) 229-4197
FAX (714) 229-4285
Circle No. 663

Teledyne Components
40 Allied Dr
Dedham, MA 02026
(617) 329-1600
FAX (617) 329-8710
Circle No. 664

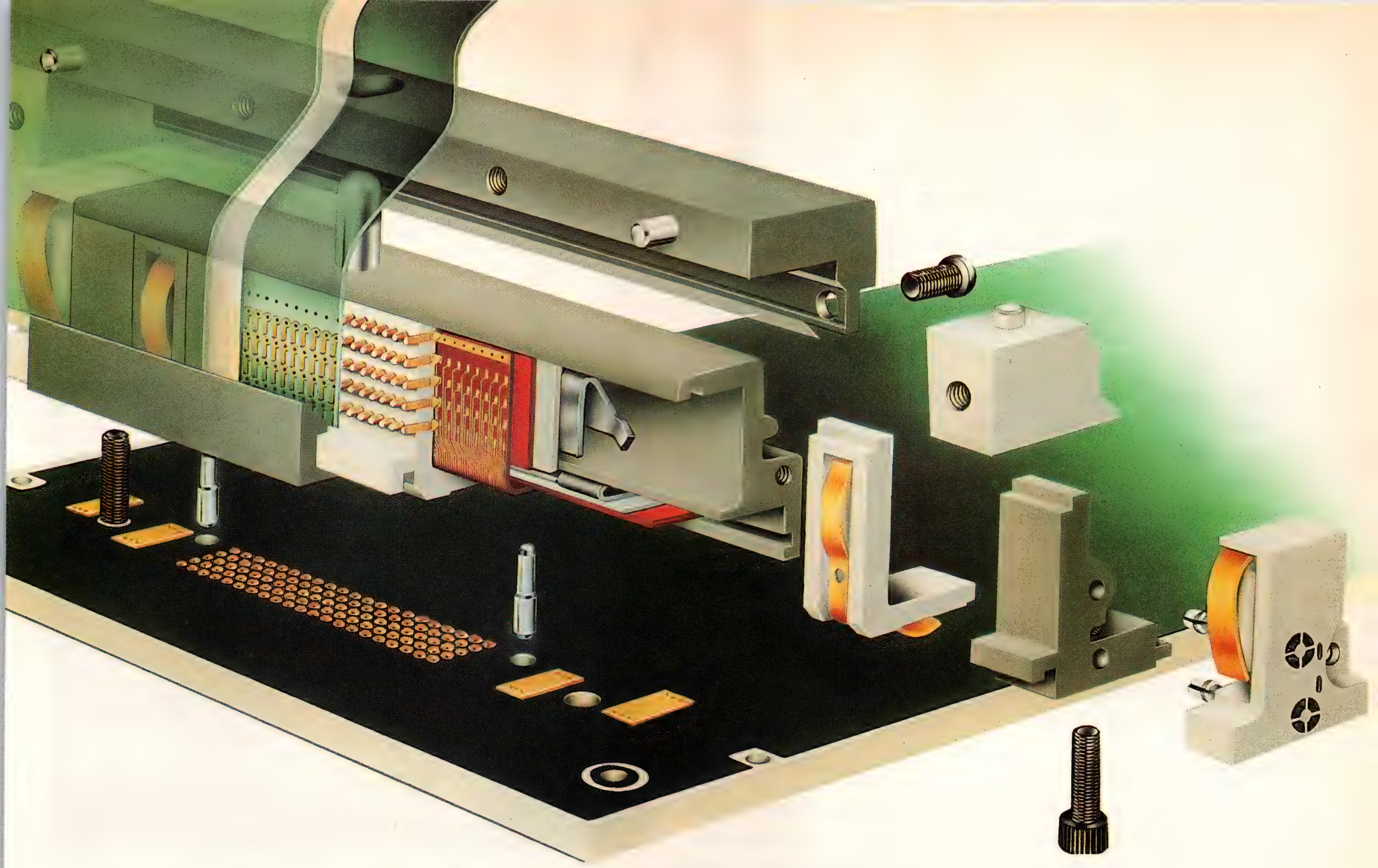
TRW LSI Products Inc
Box 2472
La Jolla, CA 92038
(619) 457-1000
FAX (619) 455-6314
Circle No. 665

Vanguard Semiconductor
211 Topaz St
Milpitas, CA 95035
(408) 946-9111
FAX (408) 263-7846
Circle No. 666

VOTE . . .

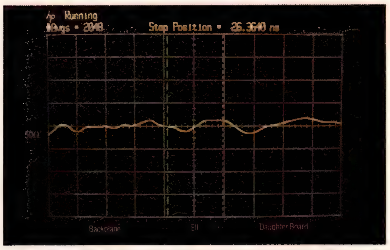
Please also use the Information Retrieval Service card to rate this article (circle one):

High Interest 512
Medium Interest 513
Low Interest 514



Out of sight performance!

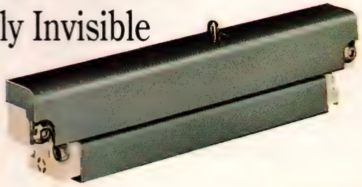
Introducing the Electronically Invisible Interconnect: transparent to high frequency signals, therefore eliminating connector induced signal distortion. Until now, the limiting factor for signal integrity in high speed electronic circuits has been the connector. The source may be matched to the load, but an impedance mismatch at the connector degrades performance. Signal integrity through EII is maintained because reflection, crosstalk, attenuation, signal skew, and rise-time degradation are reduced to absolute minimums.



EII achieves matched impedance of the connector to the backplane and daughter card.

This unprecedented performance is made possible by a unique flexible microstrip transmission line structure with a continuous ground-plane as the major signal path through the Electronically Invisible Interconnect.

Augat, the company known for quality and innovation, is now setting a new standard of performance – the Electronically Invisible Interconnect. Outta' sight!



CIRCLE NO. 64

AUGAT® *Quality and Innovation*

Augat Inc., Interconnection Products Division
33 Perry Ave., P.O. Box 779,
Attleboro, MA 02703
(508) 222-2202
FAX: (508) 222-0693

Visit us at Electro, Booth #5132, Bayside Expo Center

Knowing a little bit about the internal architectures of S/H amplifiers will help you understand the origin of various errors and thus various specifications.

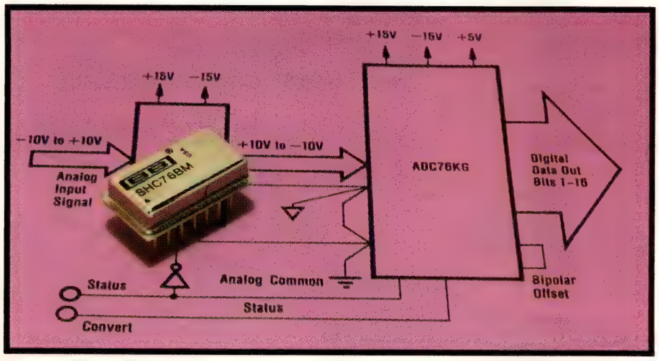
that the S/H amps with the highest feedthrough attenuation also happen to be those with the highest accuracy.

Table 2 lists the most common specs of S/H amps. However, more dynamic specs, such as distortion, are appearing on data sheets. Harris Semiconductor's latest monolithic introduction, the HA-5340, features hold-mode distortion of −72 dBc with a 5V p-p, 200-kHz input. Many manufacturers who design S/H amps as part of an ADC pair, such as Burr-Brown with its ADC701/SHC701, provide complete dynamic specifications for the pair.

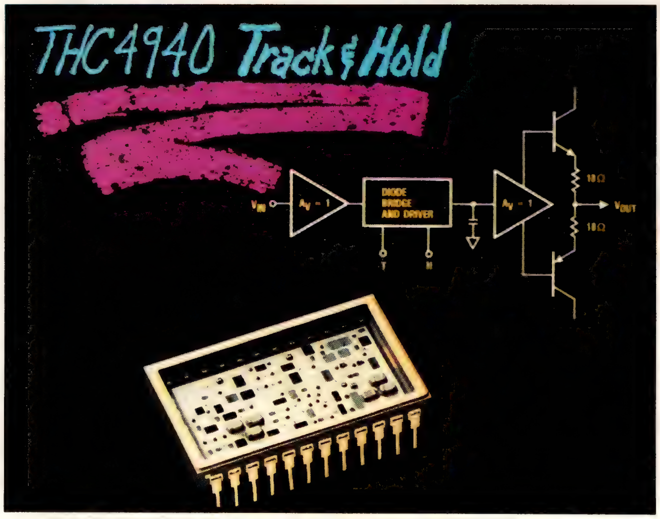
Put it all together

Acquiring data-sheet-inspection savvy is important, but ultimately you have to maintain the amp's performance in your design. Depending on your accuracy and speed requirements, the layout of analog and digital signals are critical to the performance of your sampling system. Some high-accuracy S/H amps, such as Datel's SHM-945, have differential inputs. Analog Device's AD386 includes an uncommitted differential amplifier whose output pin is next to the S/H-amp input pin. To use the differential input option you simply connect the two.

Take vital cues from the way manufacturers build their hybrids. Just as Analog Devices didn't choose to place the differential-amplifier output on the opposite side of the device from the S/H input, neither should you run sensitive analog lines around a pc board. Not only should you make the traces short, but you should also isolate the digital control lines from the analog input and output by as much as possible. Any external capacitors should be extremely close to the S/H device.



Many manufacturers design certain S/H amplifiers as companions to specific A/D converters and specify the two devices as a pair. (Photo courtesy Burr-Brown Corp)



Some S/H amplifiers have output-amplifier stages sufficient to drive flash-converter inputs. The THC4940 can drive 90-pF loads. (Courtesy TRW LSI Products)

And be sure that you keep solder flux away from the external capacitors' connection; solder flux can discharge the hold capacitor and cause a severe increase in the droop rate.

The job of extracting performance from your S/H amp goes far beyond the tips offered here. Myriad application notes and design sheets offer plenty of design ideas and layout suggestions. Take the manufacturers' advice: S/H amplifiers are definitely worthy of careful selection and respectful use. **EDN**

References

1. Jung, W, "Applying IC Sample-Hold Amplifiers," Application Note, Analog Devices, 1985.
2. Little, A, B Burnett, "S/H amp-ADC matrimony provides accurate sampling," *EDN*, February 4, 1988, pg 153.
3. Leonard, R, "Picking the right sample-and-hold amp for various data-acquisition needs," Application Note AN-2, Datel Inc, 1987.
4. Pease, R A, "The analog/digital boundary needn't be never-never land," *EDN*, September 28, 1989, pg 145.
5. Data Conversion Products Catalog, Micro Networks, 1988-1989.

Article Interest Quotient (Circle One)
High 512 Medium 513 Low 514

National Semiconductor

National's family of CMOS op amps rises to a new all-time low: 40 femtoamps.

TAKING IT TO THE LIMITS WITH ULTRA-LOW INPUT BIAS CURRENT.

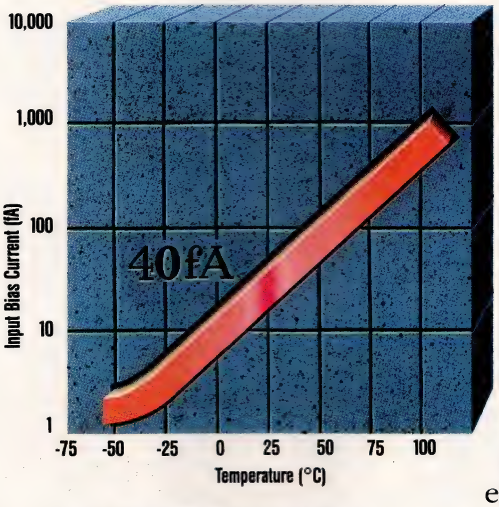
National's new quad/dual CMOS op amps, the LMC660/662 and the LPC660/662, feature an extremely low input bias current of 40 fA typical. You can't go much lower.

FEATURING RAIL-TO-RAIL OUTPUT SWING.

With a newly patented double feed-forward circuit architecture, National's op amps provide an output swing that extends from one supply rail to the other. You can't swing any more than that.

Use the LMC660/662 and LPC660/662 to drive rail-to-rail input A/Ds, or take advantage of the LMC's fully specified 600 Ω load capability to process audio in telecom and cellular radio applications. Other typical applications include:

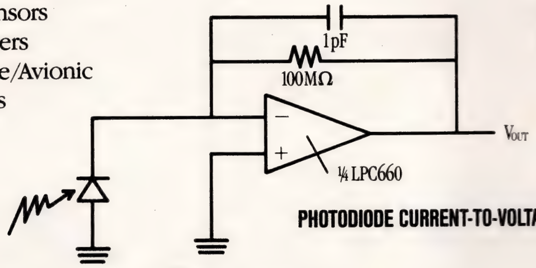
- Handheld meters
- Medical instrumentation
- Remote sensors
- Electrometers
- Spaceborne/Avionic subsystems



INPUT BIAS CURRENT VS. TEMPERATURE: 40 fA AT 25°C

NATIONAL REDEFINES SINGLE-SUPPLY OPERATION.

In the past, a single-supply op amp was an amplifier whose input common-mode range included ground. But in today's +5V systems, you need op amps that take advantage of every last volt that the supply provides, and whose outputs swing fully from rail-to-rail. National was the first to deliver rail-to-rail performance with the LMC660 and now has a complete family— all in CMOS.



PHOTODIODE CURRENT-TO-VOLTAGE CONVERTER

POWER UP WITH LOW POWER AND MICROPOWER.

If you're looking for low power, there's the LMC660/662, which operate at 375 μA/amplifier. Or if your application calls for 40 μA/amplifier, we offer the LPC660/662, micropower versions of the popular LMC series. In either case, you get lower power dissipation and a longer lasting battery.

LMC660/LPC660 VS. THE COMPETITION

	LMC660AI	LPC660AI	TLC274AI
Output Swing ($V^+ = +5V$)	**0.15V to 4.82V**	**0.03V to 4.97V**	**0.05V to 3.2V**
V_{OS} (max)	3 mV	3 mV	5 mV
I_b (typ)	40 fA	40 fA	600 fA
Supply Current (typ)	375 μA/amp	40 μA/amp	675 μA/amp

GET THE LOWDOWN.

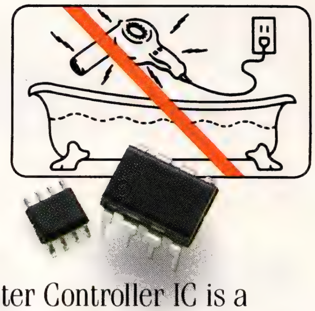
For more information on our new CMOS op amps and growing family of high-performance amplifiers, including VIP,™ Bi-FET,™ Super-Blocks,™ and precision, call or write us today: 1-800-624-9613, Ext. 66. In Canada: 1-800-548-4529, Ext. 66. National Semiconductor Corporation, P.O. Box 7643, Mt. Prospect, IL 60056-7643. And find out how we can help take your designs to new heights.

National Semiconductor

Bi-FET, Super-Blocks, and VIP are trademarks of National Semiconductor Corporation.
© 1990 National Semiconductor Corporation

We’re Redefining

Defense Technology.



We're taking our linear bipolar military experience and applying it to low cost, high volume applications. Our Ground Fault Interrupter Controller IC is a good example. By preventing electrical shock in consumer products, it gives new meaning to the term *National Defense.*

Raytheon's standard linear ICs and linear arrays are at work in dozens of commercial applications. The reason is simple. They make good business sense.

It's because in developing products our engineers look beyond basic circuit requirements to the demands of your overall system.

We're committed to analog technology. From our design kits and engineering support to our fab and plastic assembly facility, we have the experience it takes to help you develop creative, cost effective solutions.

If you'd like to know how our analog technology can meet your application's needs, call **1-800-722-7074** for our new brochure. Raytheon Company, Semiconductor Division. 350 Ellis St., Mountain View, CA 94039.

CIRCLE NO. 65

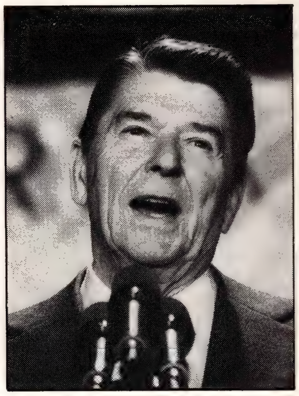
Raytheon

Where quality starts with fundamentals

In 1979, Margaret Thatcher is voted in as Prime Minister of Great Britain…

and EDN is voted #1 in readership.

In 1980, Ronald Reagan is elected President of the United States…

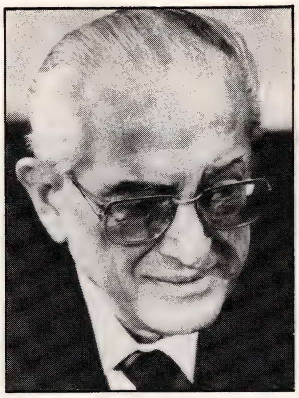


and EDN presides as #1 in readership.

In 1981, Sandra Day O'Connor is the 1st woman on the Supreme Court…

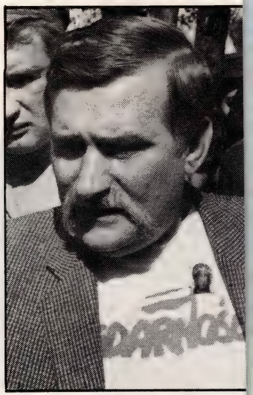
and EDN is first in readership.

In 1982, Yuri Andropov is elected as the leader of the USSR…



and EDN leads as #1 in readership.

In 1983 Lech Walesa of Poland wins the Nobel Peace Prize…



and EDN wins the #1 prize in readership.

WORLD

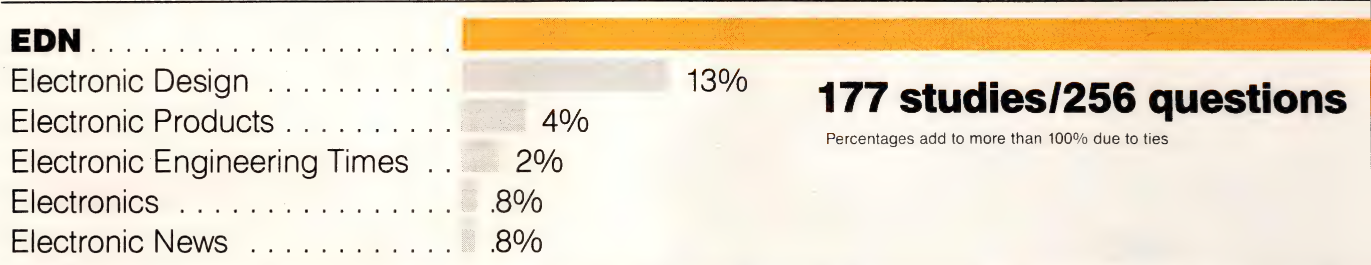
All Around The World, They Come; And They G
There Has Been Only One Leader Since 1978… ED

Winning one study doesn't make history. But winning 84% of 177 independent readership studies since 1978 makes EDN a first class world leader. That's more wins than the rest of the electronics publications combined.

Announcing 7 new EDN independen

	EDN	Electronic
Zenith Electronics	**#1**	5
Sprague Semiconductor	**#1**	5
SGS Thomson Semiconductor	**#1**	5
3M	**#1**	5
Apex Technology	**#1**	5
Sipex Corporation	**#1**	4
Kyocera Northwest, Inc.	**#1**	NOT INCL.

CUMULATIVE WINS–
% of Readership/Reader Preference Wins* 1978–1989 (to date)



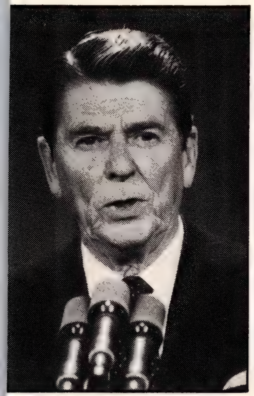
177 studies/256 questions

Percentages add to more than 100% due to ties

---

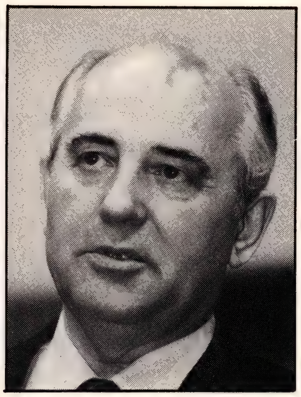
*Independent studies are conducted across customer/prospects lists or TIDS lists, not across a magazine's or newspaper's own list, which results in obvious bias. **Results based on the question

1984, Ronald Reagan
re-elected #1 in a
ndslide…



d EDN is re-elected #1
a readership landslide.

In 1985, Mikhail Gorbachev
is elected as the leader
of the USSR…



and EDN is elected the
leader in readership.

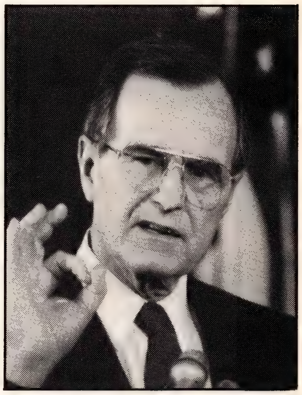
In 1986, Corazon Aquino
is chosen as the President
of the Philippines…

and EDN is chosen as #1 in
readership.

In 1987, Margaret Thatcher
wins a third term
as Prime Minister…

and EDN wins another year
as the leader in readership.

In 1988, George Bush is
elected to highest office
in the United States…



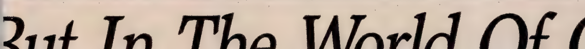
and EDN holds the #1 spot
in readership.

EADERS

ut In The World Of Covering Electronics Technology, nd EDN's Leadership In Readership Reign Continues.

eadership/reader preference study*wins:*

Electronic Design	Electronic Products	EE Times	Electronic News
2	4	3	NOT INCL.
2	4	3	NOT INCL.
4	3	2	NOT INCL.
2	4	3	6
2	3	4	NOT INCL.
2	NOT INCL.	3	NOT INCL.
3	2	4	5



If you would like to see the complete record of EDN's readership wins, contact your local sales representative. EDN will send you a six-foot long brochure that proves history repeats itself.

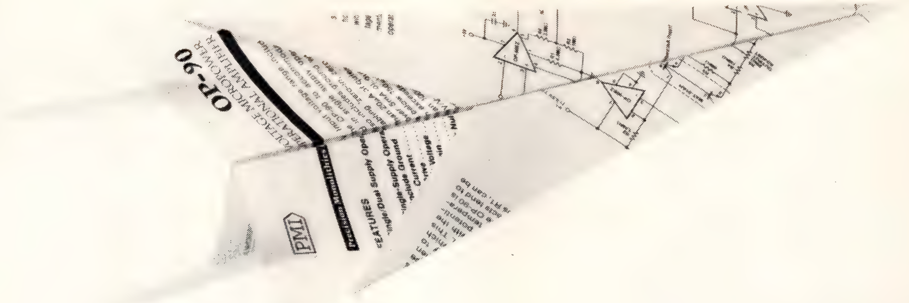
And only a leader dares to offer $1000 to anyone who can disprove its claim to readership. No other electronic engineering magazine or newspaper in the US or throughout the world has won more independent readership/reader preference studies than EDN.

EDN Magazine Edition
News Edition

A Partnership in Power & Prestige Worldwide

---

hich of these publications do you read regularly (3 out of 4 issues)?" in each study.



More Precision. Micro Power. Mini Price.

Power is costly . . . but PMI's broad line of micropower/low power op amps is not. And, all come with the precision performance you've come to expect from PMI.

We've got them all – singles, duals, quads– with supply current as low as a mere 200nA. Check the table for the PMI micropower/low power op amp that meets your needs at new lower prices!

All of our devices are available in small outline (SO) packages plus plastic DIP, CerDIP, LCC, and as dice. And, we've extended the temperature range from 0°C/70°C to –40°C/+85°C to bring you added value at no extra cost. Full 883 versions available too, of course!

If you need a cost-effective solution to your amplifier requirements, call us first at **(800) 843-1515** or FAX us at (408) 727-1550. Or, circle the reader service number below for information on the industry's broadest family of micropower/low power op amps.

PMI's Micropower/Low Power Op Amp Family

	Single	Dual	Quad	Max I_{SY} per Amp	Max V_{OS} (single)
Precision, µPower	OP-90	OP-290	OP-490	20µA	150µV
General Purpose	OP-20	OP-220	OP-420	55µA	250µV
Fast	OP-21	OP-221	OP-421	230µA	100µV
Programmable	OP-22	—	—	200nA - 400µA	300µV
Fast, Programmable	OP-32	—	—	200nA - 2mA	300µV
Low I_b, CMOS	OP-80	—	—	325µA	1.5mV
Precision, Low Power	OP-97	OP-297	—	600µA	25µV

PMI®

PMI – your partner in analog integrated circuits.

Precision Monolithics Inc.
1500 Space Park Drive
Santa Clara, California 95054-3434

ALTAMONTE SPRINGS: (407) 831-8233, **ATLANTA**: (404) 263-7995, **BOSTON**: (508) 794-0026, **CHICAGO**: (312) 250-0808, **DALLAS**: (214) 690-3495, **DENVER**: (303) 792-9595, **DETROIT**: (313) 930-2051, **LOS ANGELES**: (818) 886-6881, **MILPITAS**: (408) 263-9366, **ORANGE COUNTY**: (714) 637-9602, **PHILADELPHIA**: (215) 953-1070

CIRCLE NO. 70

EDN'S
ALL-STAR
PC

PART 5:

ENGINEERING SOFTWARE

After months of development, chronicled in four previous articles, it's time for the All-Star PC to do more than run operating systems, benchmarks, and utility programs. It's time to do real work by running engineering software.

PCs provide engineers with access to a wide array of hardware- and software-development tools, and EDN's All-Star PC excels at running them. The All-Star PC represents the pinnacle of PC technology—at least until the next wave of PC-related component introductions transform today's top performers into yesterday's news.

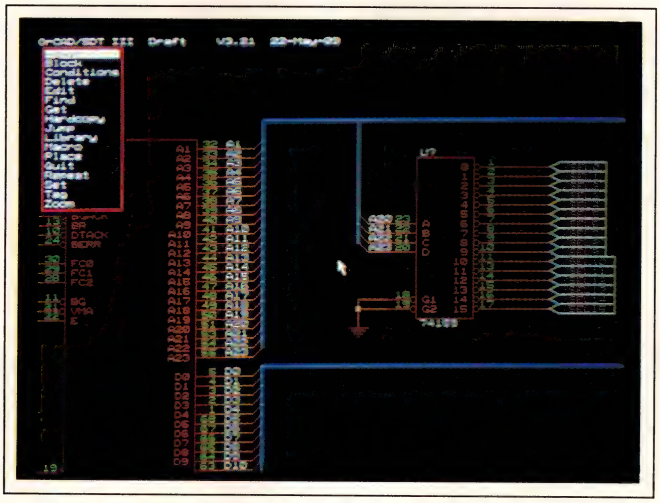
In a mere eight years, the PC has become a vital engineering tool for product development. The range of development software available for PCs numbs the mind. There are PC-based software packages for all imaginable product-development needs. These packages include software-development tools such as cross-assemblers, cross-compilers, debuggers, and version-management packages; circuit-development tools such as schematic-drafting packages, pc-board-layout tools, thermal-analysis packages, analog- and digital-circuit simulators, ASIC-development packages, and mechanical CAD packages for designing packaging; hybrid hardware/software products such as in-circuit emulators, PC-based EPROM programmers, and tools for designing PLDs and field-programmable gate arrays; and even pro-

---

STEVEN H LEIBSON,
Senior Regional Editor

ject-management packages, which help keep your project on course.

You can also use your PC to generate proposals, progress reports, memos, and product documentation, using the general-business software developed for the PC such as word-processing software, desktop-publishing packages, spreadsheets, and database managers. Best of all, because of the PC's huge sales volumes and the resulting competition among products, these engineering- and business-software packages include some of the highest quality, lowest-priced software products for any computer ever placed on the market.



Drop-down menus allow OrCAD/SDT III to use the entire screen as a drafting area.

No one article could possibly cover all of the software products listed above. An entire issue of EDN devoted to the topic wouldn't suffice. Instead, we'll focus on two core tasks that nearly every electrical engineer performs when developing a product: circuit design and the associated pc-board development. The other types of product-development software packages are just as important, but no software product stresses a computer's abilities more than schematic drafting and pc-board layout. Schematics, circuit-board designs, and component databases consume large amounts of disk space, require plenty of RAM for efficient manipulation, and can use all the computing horsepower a PC can muster. In addition, schematic drafting, component placement, and trace routing push the limits of human concentration and consequently place heavy demands on a computer's user interface. For these reasons, schematic-drafting and pc-board-layout packages make for excellent tests of the All-Star PC's abilities.

The PC marketplace is flush with schematic-drafting and pc-board-layout products, making an exhaustive test of all available products impossible, and even making a choice difficult. The two well-known software-product families that provided the final shakedown tests for EDN's All-Star PC, OrCAD and Personal CAD Systems' (P-CAD) Master Designer, dwell at opposite ends of the product spectrum. OrCAD products will run on just about any PC, from vintage 8088-based PCs to 80486-based behemoths like the All-Star PC. OrCAD's design tools need 640k bytes of RAM (but won't use more), require a minimal amount of disk space (you don't even need a hard disk), don't require a mouse (although they can work with one), and include display drivers for nearly every dumb PC display card ever marketed (but don't support intelligent graphics cards). The P-CAD product family, on the other hand, consists of high-end tools that require at least an 80286 µP, can use as much as 16M bytes of RAM, require 20M bytes of hard-disk space and a 1.2M-byte floppy-disk drive, work substantially better with a mouse, and include drivers for both dumb and intelligent graphics cards.

Despite OrCAD's populist approach to software, its development tools provide excellent design capabilities. Central to the product family is OrCAD/SDT III, the schematic-drafting package. The company's pc-board, PLD, and simulation products can all accept schematics created with OrCAD/SDT III. Other companies have also created products that accept OrCAD's schematics. For example, International Microcircuits Inc (Milpitas, CA, (408) 263-6300) recently announced a PC-based development system for its Easygate gate-array design package that employs OrCAD/SDT III as its front-end design tool to create ASICs with as many as 16,000 gates.

OrCAD/SDT III handles hierarchical designs with 200 levels and features pop-up menus for ease of use. The package also includes a library containing more than 6000 parts. The pop-up windows minimize the need to read the manual. I was drawing schematics only minutes after installing the software. Although OrCAD/SDT III only supports dumb graphic-display cards, it is still quite fast, and it can operate displays at screen resolu-

EDN's PC All-Stars

OrCAD

OrCAD Systems Corp, 3175 NW
Aloclek Dr, Hillsboro, OR 97124.
(503) 690-9881. FAX (503) 690-9891. TWX 910-240-2090.
Circle No. 667

STATS:
SCHEMATIC-DRAFTING TOOL: OrCAD/SDT III
PC-BOARD-LAYOUT TOOL: OrCAD/PCB II (includes automatic router)
PLD DESIGN TOOLS: OrCAD/PLD and OrCAD/Mod
SIMULATOR: OrCAD/VST
RAM REQUIRED: 640k bytes
PROCESSOR REQUIRED: Any 80×86-compatible μP

BIO: The OrCAD family of development tools runs on nearly every PC, yet it includes many high-end features such as hierarchical design, simulation support, and pop-up menus. The pc-board-layout tool, OrCAD PCB II, can handle boards as large as 32×32 in. with a 0.001-in. resolution.

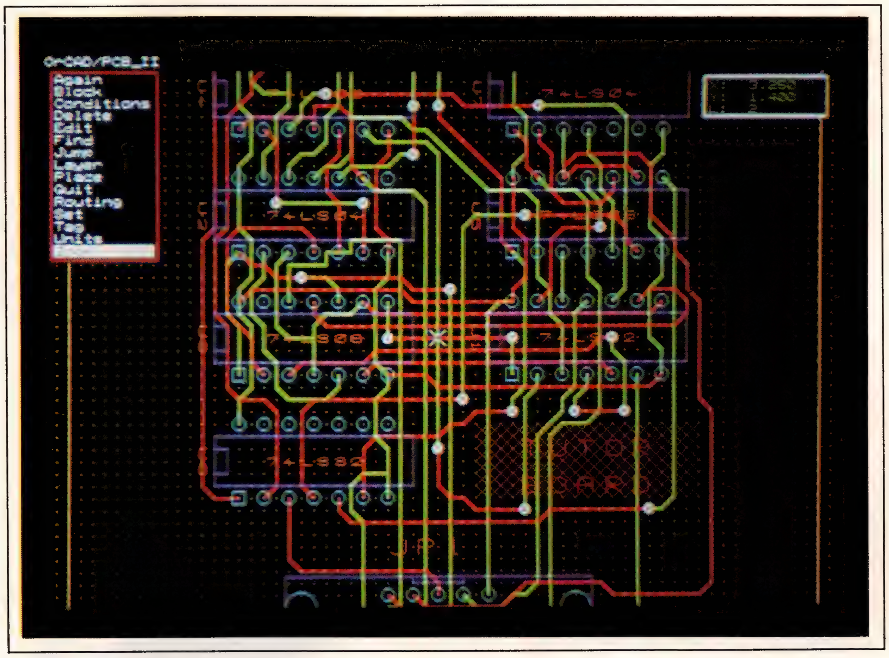
tions as high as 800×600 pixels. To see what display resolution might be acceptable, I set all of the OrCAD tools to the standard VGA resolution of 640×480 pixels, which worked just fine for schematic drafting and for pc-board layout.

OrCAD/SDT III's schematics feed OrCAD/PCB II (the company's pc-board design tool), OrCAD/VST (a digital simulator), and two PLD design tools, OrCAD/PLD and OrCAD/Mod. The pc-board-layout package can accommodate boards as large as 32×32 in. with a resolution of 0.001 in. It can handle designs with as many as 270 equivalent (14-pin) ICs, 5200 pads, and 16 copper layers—a significant capacity considering that the program and the design database must both fit into 640k bytes. OrCAD/PCB II incorporates an automatic pc-board router and allows you to manually route a board as well. Once again, OrCAD's tutorial enables you to learn OrCAD/PCB II in a matter of minutes.

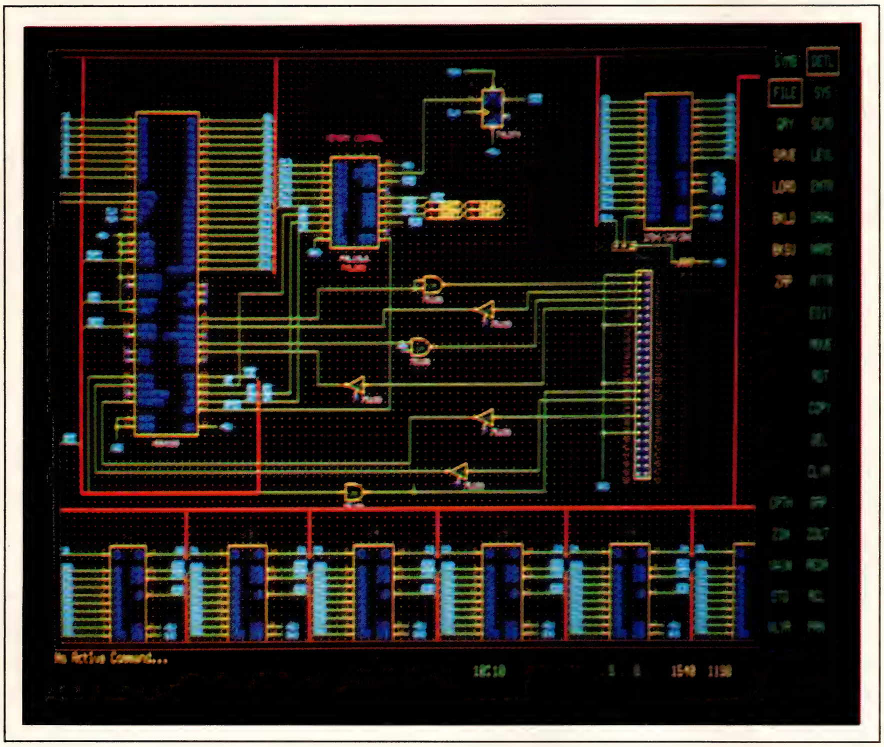
OrCAD/VST is a 12-state, event-driven logic simulator that accommodates designs with as many as 14,000 gates, limited once again by the 640k-byte barrier. The company claims that the simulator can evaluate 65,000 events/sec on a 20-MHz 80386-based PC. I had never used a digital simulator, and I found OrCAD/VST easy to set up and use. The simulator's output resembles a logic analyzer's display, making the simulation results easy for a hardware engineer like me to understand. I didn't try OrCAD/PLD or OrCAD/Mod, the two PLD design tools, because an article covering such tools will appear in EDN later this year.

The Master Designer tool set from P-CAD handles larger designs than OrCad. Consequently, it requires more PC processing power (it doesn't run on 8088-based PCs) and greater storage capacity; the company recommends that you have 20M bytes of hard-disk space available. The Master Designer can use expanded memory, and in fact, the system-overview booklet that accompanies the package states that expanded memory is "highly recommended." The latest version of Master Designer, release 4.5, supports display-list processing for intelligent graphics cards. The company claims a 20-fold speed improvement in redrawing the screen with intelligent display adapters. I combined the Master Designer's DGIS (direct graphics interface standard) display driver with the DGIS software for NEC's Multisync Graphics Engine and was able to use the display card's 1024×768-pixel mode. This configuration proved excellent for schematic drafting and pc-board layout; it allows you to view a large portion of your design while preserving fine details and text.

By taking advantage of the more powerful features of high-end PCs,



Although not essential for schematic drafting, color displays are indispensable for pc-board-layout programs such as OrCAD/PCB II.



At 1024 × 768 pixels, the schematic-capture portion of P-CAD's Master Designer can display a substantial part of your schematic and still keep text readable. Support for intelligent graphics adapters allows Master Designer to rapidly absorb advances in PC display technology.

the Master Designer can tackle large jobs. PC-Caps, the schematic-drafting package, handles multisheet schematics with as many as 300 sheets and hierarchical designs with as many as 15 levels. PC-Cards, the pc-board-layout package, accommodates boards as large as 60 × 60 in. with 100 layers at 0.001-in. or 0.01-mm resolution. The Master Designer deals with designs containing as many as 2500 components and 32,000 pins.

Many ways to use a menu

Three of the Master Designer's major components—PC-Caps, PC-Cards, and PC-Place (the component-placement tool)—employ a permanent menu on the right side of the screen that complements a main drafting area. Selecting a menu item throws a submenu onto the screen in a gap between the main menu and the drafting area. You can select among these menu entries with a mouse, with the cursor-control keys, or by typing a slash, to invoke the command-line entry mode, and the first three letters of a menu or submenu command. The fourth major component, the automatic router PC-Route, also employs menus, but it presents them as screens of text that allow you to select the routing parameters before starting the route.

A complicated network of utility programs links the four main modules. For example, to prepare a schematic for placement and routing, you must process the schematic with PC-Nodes to create a net list, PC-Link to join multisheet and hierarchical designs into one master net list, and PC-Pack, which uses the master net list to assign logical gates to physical packages. Once all components are packaged, you can place them on the pc board with PC-Place and then route the signals with PC-Cards and PC-Route. Other utility programs perform design-rule checks, back-annotation, which transfers design changes made on the pc board back to the schematic, and a variety of manufacturing-related tasks such as creating component and materials lists.

Master Designer's 2-in.-thick tutorial takes hours to complete. However, you'll have a good idea of what the package can do by the time you finish it. The company also provides a system map that shows you how all of the 17 programs in the Master Designer package interrelate. The large number of interlocking programs makes the Master Designer package somewhat confusing, but after working through the tutorials and studying the system map, the relationships among the various programs become clear. The Master Designer includes a text-based shell program that helps you move from program to program within the Master Designer family, but you must still acquire a good understanding of the product's interlocking parts before you can make efficient use of the package.

Both the OrCAD and P-CAD products had no trouble running on the All-Star PC. It's impossible to rank one over the other, however, because the two packages are clearly aimed at different markets. OrCAD lets you create smaller designs on almost any PC. P-CAD's Master Designer takes on large designs but requires more speed and capacity from a PC. Product-design engineers wrestle with a range of design problems, so no one tool is going to meet everyone's needs. However, by adopting the PC as your design computer, you can

EDN's PC All-Stars **Master Designer**

Personal CAD Systems Inc,
1290 Parkmoor Ave, San Jose,
CA 95126. (408) 971-1300. FAX
(408) 279-3752. TLX 371799.
Circle No. 668

BIO: P-CAD's product family supports intelligent graphics cards and can use a PC's expanded memory to enhance the software's ability to handle very large designs. Its PC-Cards pc-board-layout tool can accommodate boards as large as 60×60 in. with 0.001-in. or 0.01-mm resolution.

STATS:
SCHEMATIC-DRAFTING TOOL: PC-Caps
PC-BOARD-LAYOUT TOOL: PC-Cards
AUTOMATIC ROUTER: PC-Route
RAM REQUIRED (MIN/MAX): 640k/16M bytes
HARD-DISK SPACE REQUIRED: 20M bytes
PROCESSOR REQUIRED: 80286 or 80386-family μP

The CAD Showdown

The Woodland Hills Country Club in California's San Fernando Valley makes an unlikely venue for a PC-based CAD software competition, but that is where Compudraft Engineering (Chatsworth, CA, (818) 709-0202) held its third annual CAD Showdown on February 7 and 8. Compudraft sells several PC-based CAD packages and provides pc-board-design services. Of the 54 CAD software vendors invited to the event, 12 companies with full-featured schematic-capture/pc-board-layout products attended. Two companies that offer stand-alone PC-based router packages also participated.

This year's meet put software products to three tests. Benchmark 1 required the entrants to create a schematic and pc-board layout for a design composed of approximately 75% digital and 25% analog components. Participants could elect to create a surface-mount version of the design in addition to the mandatory through-hole version. Benchmark 2 required building a denser pc board, incorporating only digital components. The last benchmark was a simulation exercise. Benchmarks 1 and 2 measured the ease of schematic entry (measured by the time required to enter the drawings), the ease of pc-board creation (measured by the time required to draw the board's outline and place the components), and the speed and efficacy of the software packages' automatic routers. Twelve companies completed the first benchmark, four of which also completed the surface-mount version. Nine companies completed Benchmark 2. Only two companies tackled the simulation problem.

Nearly every participating vendor claims to have won this year's showdown. Because there are few uniquely correct solutions in engineering or in pc-board design, it's impossible to declare a winner. You must settle issues such as which company had the better CAD operator, how much difference the computers made (the machines used by the different companies incorporated a variety of processors operating at different clock speeds), and whether a 2-layer board with many vias is better (cheaper to build, more manufacturable, or prettier) than a 4-layer design with fewer vias. You must also consider the cost of the CAD software when trying to determine an overall winner.

These factors' relative importance depends on your particular circumstances, so you're far better off ordering the *CAD Showdown 3 Official Results* book ($25, plus $2.50 for handling) from Compudraft and then declaring your own winner. Despite the brouhaha generated by this year's event, Compudraft plans to sponsor another showdown next year.

choose among many possible design tools. (For more information about the various PC-based design tools, see **box**, "The CAD Showdown".)

Master Designer and the OrCAD tools run under DOS. OrCAD's products simply acquiesce to DOS's 640k-byte barrier; Master Designer circumvents the barrier by using expanded memory. The rapidly aging operating system gets in the way of programs like these design tools, which are trying to tackle big jobs. Because PCs based on the 80386 µP are readily available and have been on the market for some time, the installed base of machines now exists to profitably support a more capable operating system.

Unix and OS/2 version 2.0 are the two prime candidates for this succession (**Ref** 8). Both operating systems support large memory models and feature graphical user interfaces that make intelligent graphics display cards practical. The All-Star PC runs both Unix and OS/2, so it is ready when the application software for these two operating systems becomes more common. Several CAD and CAE vendors already offer Unix-based engineering software, though not yet targeted at the PC. Other vendors are starting to offer OS/2 versions of their engineering software. For example, EEsof (Westlake Village, CA, (818) 991-7530) offers versions of its microwave and RF design tools that run under OS/2.

However, until Unix or OS/2 takes over the PC arena, engineering-software packages that run under DOS continue to solve many of today's problems. One of EDN's motives for building the All-Star PC was to evaluate all this software. That's exactly what the All-Star PC will do in the future.

The author with his creation—the All-Star PC.

References

1. Conner, Margery, "CASE for embedded systems: New software tools speed design and debug," *EDN*, January 18, 1990, pg 95.

2. Leibson, Steven H, "In-circuit emulators for µCs probe software activity in a closed environment," *EDN*, July 20, 1989, pg 64.

3. Leibson, Steven H, "Universal cross-assemblers: Software tools handle all µP traffic," *EDN*, June 8, 1989, pg 89.

4. Mosley, J D, "PCs become low-cost imaging systems," *EDN*, August 3, 1989, pg 81.

5. Small, Charles H, "ROM emulation reaches far-flung fields," *EDN*, March 1, 1990, pg 57.

6. Swager, Anne Watson, "Thermal-analysis software: Thermal images provide reliability clues," *EDN*, February 1, 1990, pg 47.

7. Wright, Maury, "SCSI development systems: Tools allow debugging of software, firmware," *EDN*, January 5, 1989, pg 87.

8. Leibson, Steven H, "Operating-System Software," *EDN*, April 26, 1990, pg 171.

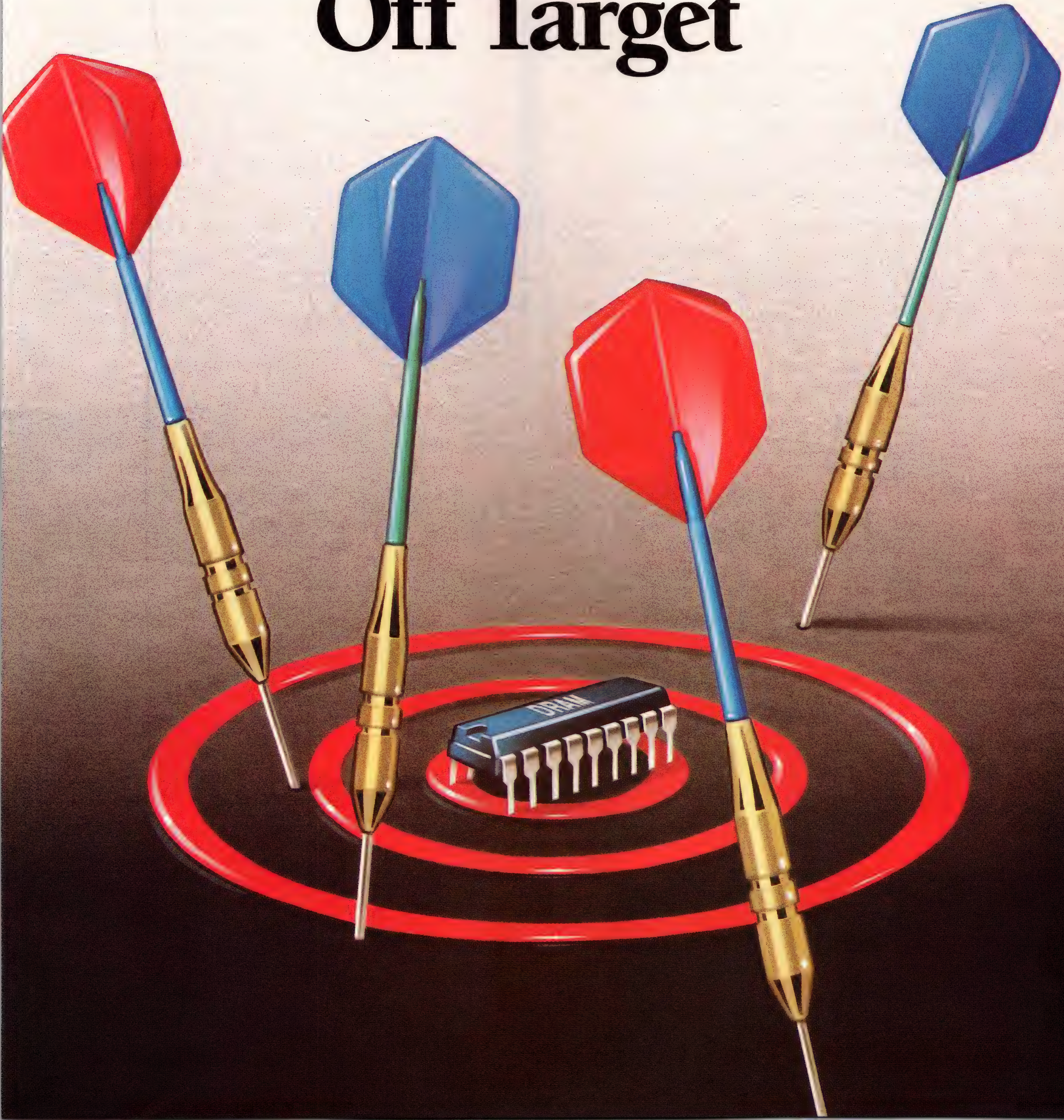
Sculpture by Kathy Jeffers/Sculpture Photography by Chris Vincent. Photography by Steven Leibson and The Photo Works unless otherwise noted.

Article Interest Quotient
(Circle One)
High 515 Medium 516 Low 517

Acknowledgment

No project as complex as the All-Star PC can be executed by one person. I received a tremendous amount of help from many people, and I've already named several throughout this series. Now I want to especially thank four people at Cheetah International's R&D lab in Colorado Springs for assisting me over the course of the project and allowing me to use their facilities. Robert Dupont, Cheetah's engineering development services manager, tried several of the PC-based engineering packages for me and summarized their assets and liabilities. Karin Law, Cheetah's director of purchasing and production, sat with me on a cold concrete floor in the back of an electronic junk shop and rummaged through boxes of unsorted parts to find the nylon standoffs we needed to mount the All-Star PC's mother board to its chassis. Leah Phipps, an associate layout designer at Cheetah, constantly lent her support. And finally, I especially want to thank Cheetah's president, Ron Sartore, who knows more about PC hardware than any ten people I've met. Without his help and expertise, EDN's All-Star PC Project would never have succeeded. No project manager ever had a better team.

If This is How You Think of Oki—You're Way Off Target



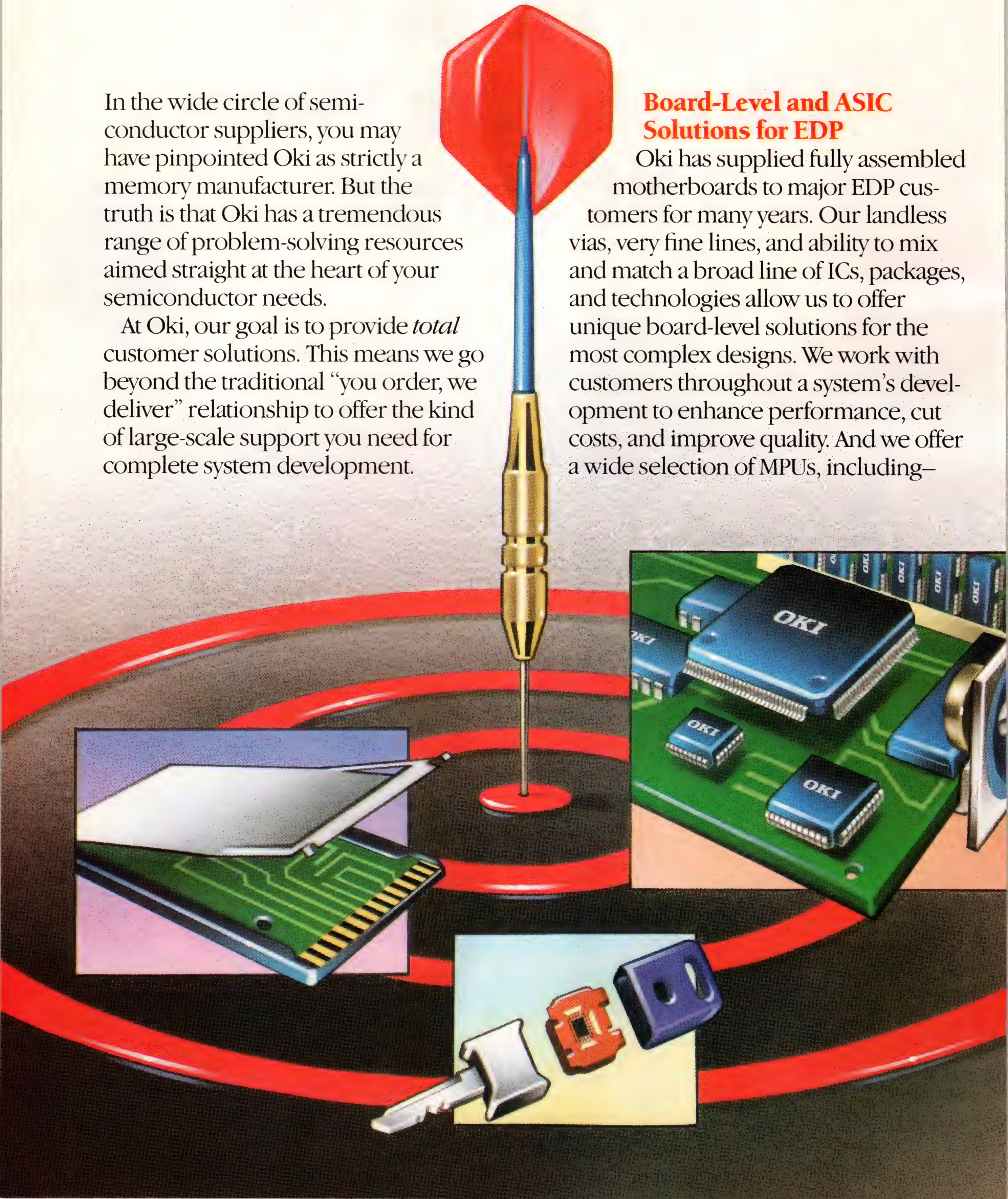
Our Aim is to Provide

In the wide circle of semiconductor suppliers, you may have pinpointed Oki as strictly a memory manufacturer. But the truth is that Oki has a tremendous range of problem-solving resources aimed straight at the heart of your semiconductor needs.

At Oki, our goal is to provide *total* customer solutions. This means we go beyond the traditional "you order, we deliver" relationship to offer the kind of large-scale support you need for complete system development.

Board-Level and ASIC Solutions for EDP

Oki has supplied fully assembled motherboards to major EDP customers for many years. Our landless vias, very fine lines, and ability to mix and match a broad line of ICs, packages, and technologies allow us to offer unique board-level solutions for the most complex designs. We work with customers throughout a system's development to enhance performance, cut costs, and improve quality. And we offer a wide selection of MPUs, including–



Total Customer Solutions

in 1990–our new 32-bit, high-speed pixel processor for true WYSIWYG displays and PostScript® laser graphic printouts. Choose from a variety of SRAMs, DRAMs, and SIMMs. And from a range of ASIC options, including 1.0 and 0.8 micron sea-of-gate, standard cell, gate array, and full custom architectures.

> *Oki goes beyond the traditional "you order, we deliver" relationship to offer the kind of large-scale support you need for complete system development.*

High-Quality Synthesizers for Sophisticated Communications

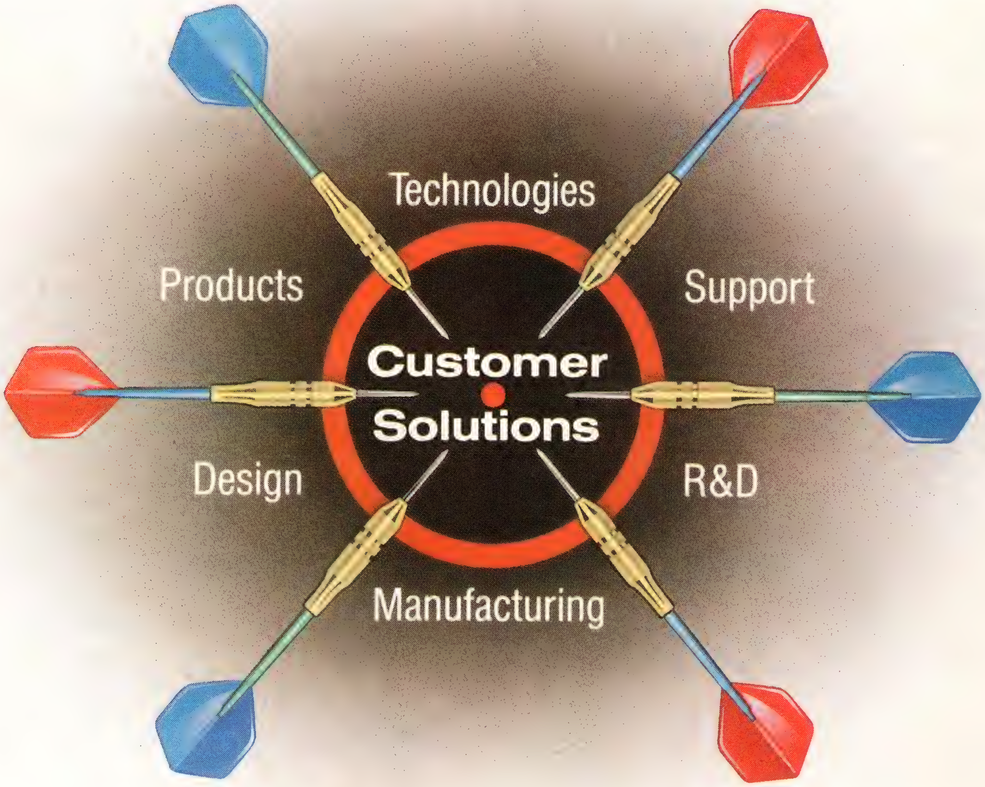
Among the solutions Oki offers for communications applications is a highly integrated, easy-to-use family of speech synthesizers: three ROM-based chips allowing 10- to 40-second messages, a solid state recorder, an OTP-based device for customized messages, and a development chip. Our superior Real-Voice™ technology provides the best sound quality available. From single-chip to complete board-level support, Oki has the resources you need for sophisticated phonemail, pager, and text-to-speech applications.

Advanced Electronics for Automotive Applications

For more than a decade, Oki has been supporting the automotive industry with a variety of advanced electronics. Our IC and module solutions for new-generation applications include keyless entry, IC/smart cards, voice recognition ICs, and vacuum fluorescent display drivers with on-chip dimming control. We offer leading-edge packaging technology such as TAB. Ideally suited for automotive applications, TAB provides high-package and high-pinout density. Plus we're able to integrate several devices on TAB–even capacitors–for hybrid TAB requirements. Other packaging options include COB, COG, and flip-chip.

CIRCLE NO. 68

Targeting Our Resources to Make You a Winner



If you're tired of darting around from one electronics manufacturer to another, we invite you to explore the advantages of a multi-resource supplier. Oki offers expertise in a wide range of process and packaging technologies. State-of-the-art manufacturing facilities–in the U.S. and abroad. Statistical process control. And the solid commitment to support you–from design concept to system completion.

Whether the problem you're aimed at solving involves a single IC or a complex system–Oki's resources are targeted toward solving that problem. Call Oki today to learn how we've helped customers gain some impressive wins in the marketplace. Then let us put our powerful resources to work for you.

OKI
Semiconductor

Transforming technology into customer solutions

So. Calif.
(Irvine)
714/752-1843
(Tarzana)
818/774-9091
No. Calif.
(San Jose)
408/244-9666
Boca Raton, FL
407/394-6099

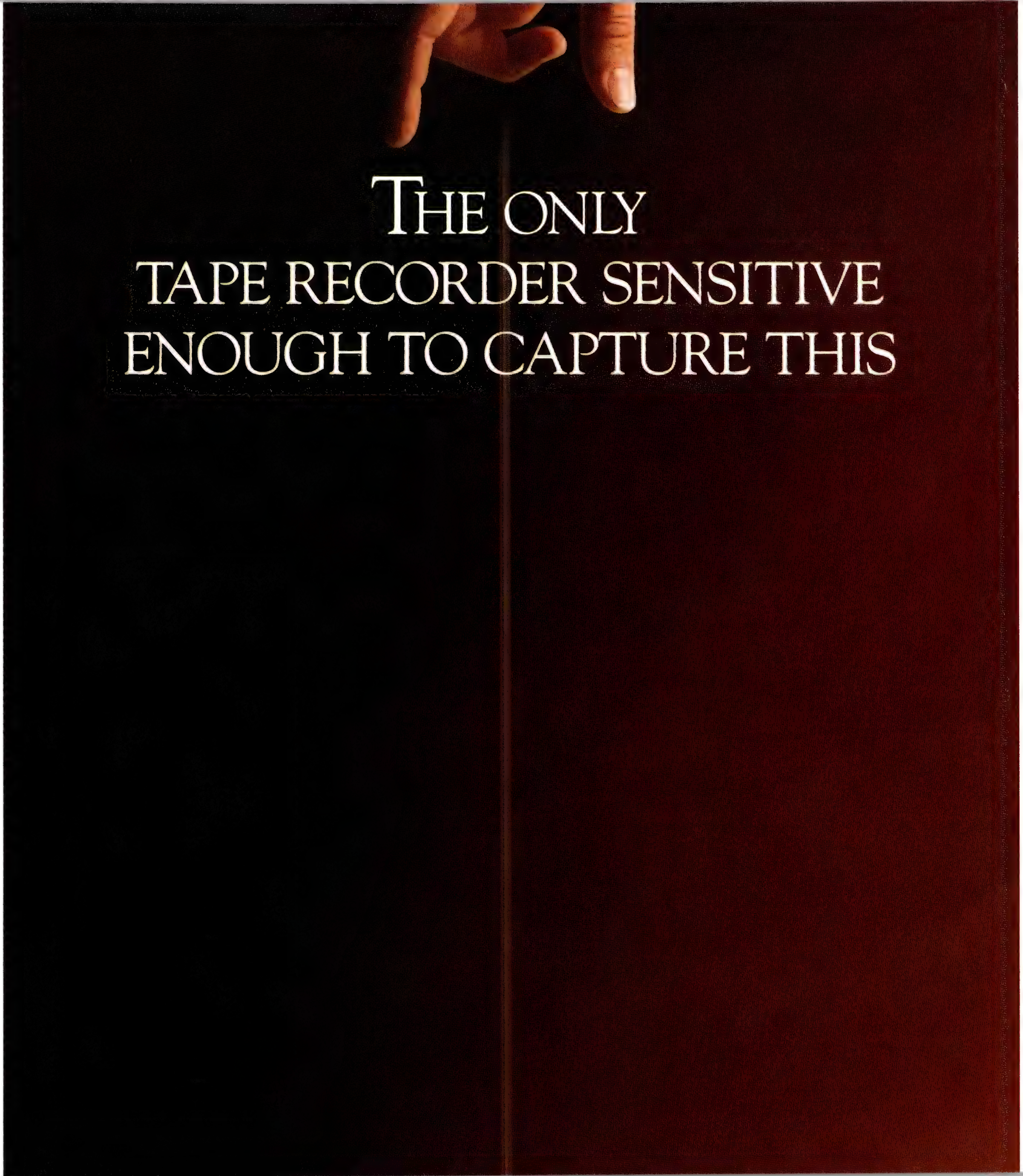
Atlanta, GA
(Norcross)
404/448-7111
Chicago, IL
(Rolling Meadows)
708/870-1400
Boston, MA
(Stoneham)
617/279-0293
Detroit, MI
(Livonia)
313/464-7200

New York, NY
(Poughkeepsie)
914/473-8044
Philadelphia, PA
(Horsham)
215/674-9511
Dallas, TX
(Richardson)
214/690-6868

PostScript is a registered trademark of Adobe Systems Incorporated.
RealVoice is a trademark of Oki Semiconductor.

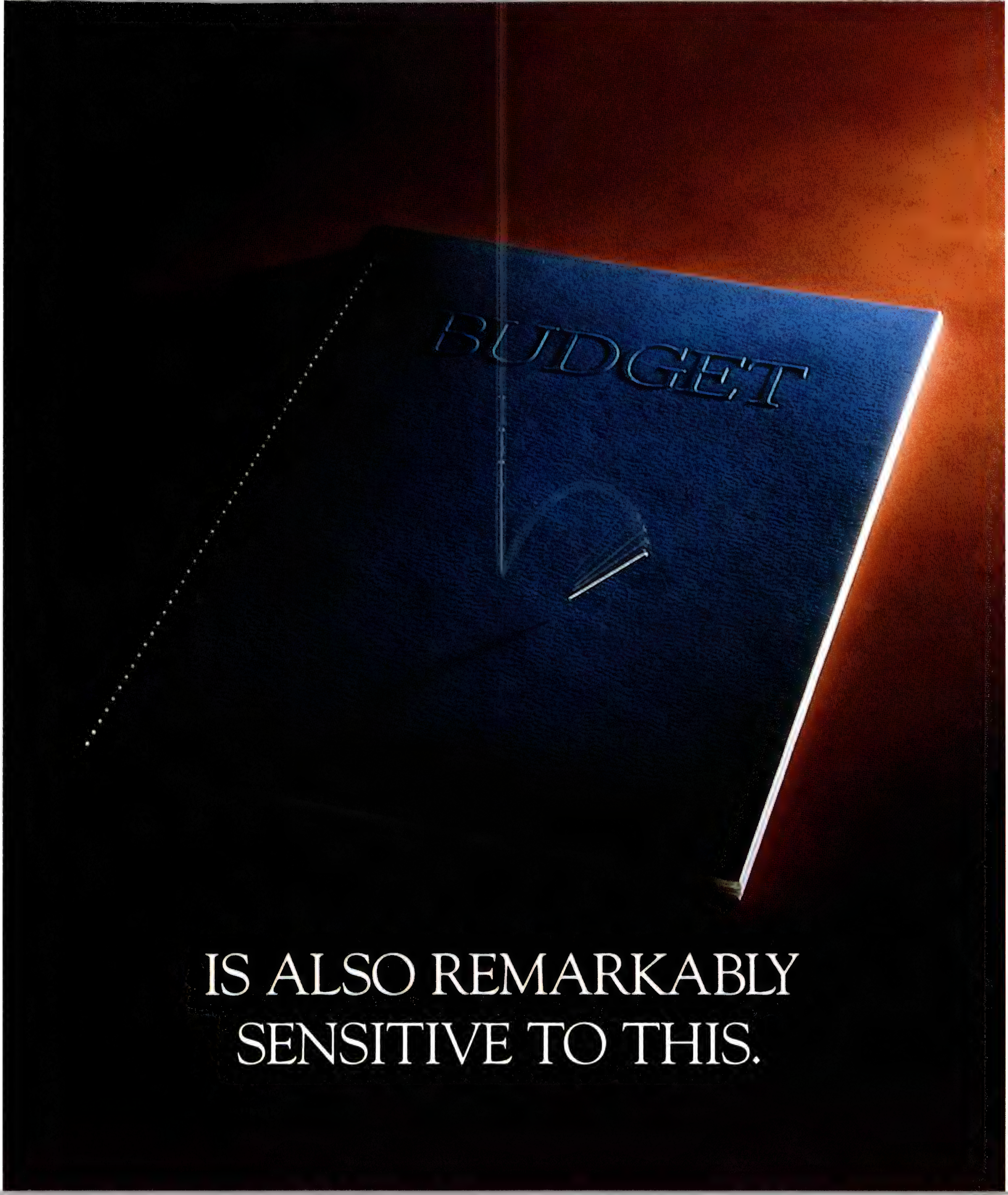
CIRCLE NO. 69

HOW TO GO FROM
ANALOG TO DIGITAL
FASTER THAN YOU CAN
TURN THIS PAGE.


THE ONLY
TAPE RECORDER SENSITIVE
ENOUGH TO CAPTURE THIS

high-quality industrial/broadcast transport technology for the RSR 512. More than 30 years of design experience in data path electronics have enabled us to develop an advanced ***digital servosystem*** using the latest microprocessor controllers.

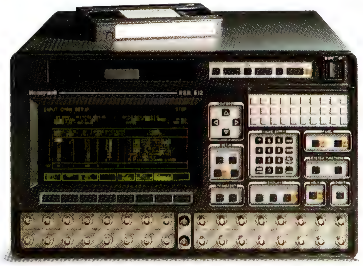
The digital ***helical scan recording*** employed by the RSR 512 offers several advantages over the longitudinal recording used on today's FM data recorders without adding cost. Unlike longitudinal recording, the digital recording technique does not restrict all channels to the same frequency response at a given tape speed. With the ***programmable bandwidth*** of the RSR 512, each channel can be selected for a bandwidth appropriate to the input data, from dc to 80 kHz in 13 binary steps. This feature



and output signals.

When you add a modest price tag to such features, performance and reliability, the Honeywell Model RSR 512 displays an unmatched sensitivity to value.

For additional information, contact ***Darrell Petersen*** at Honeywell Test Instruments Division, Box 5227, Denver, CO 80217-5227. (303) 773-4835. Asia Pacific (852-5) 8298298. Canada (613) 224-3822. Europe 32 (02) 728-24-79. Japan (81)-3-777-5141.



Honeywell

HELPING YOU CONTROL YOUR WORLD

Honeywell's ***Model RSR 512*** (Rotary Storage Recorder) makes common sense as well as technical sense.

It has excellent dynamic range, reliable performance and a ***complete package*** of special features that make it hard to beat. And its surprisingly modest price tag makes it hard to resist.

The Model RSR 512 is a precision voltage recorder that incorporates better than a ***70 dB dynamic range***—a full order of magnitude improvement over today's FM data recorders. To accomplish this feat, Honeywell has combined the characteristics of FM recording with the added accuracy of digital recording. Your analog data is stored digitally on tape, and can be played back in either digital or analog form.

The ***digital technology*** incorporated into the RSR 512 also means better recording fidelity, and data transfer to computers that is both ***easy and fast***. The technologies incorporated into the RSR 512 are well-developed and proven.

Honeywell chose the worldwide standard low-cost ***½" T-120 videocassette medium*** along with proven,

allows you to maximize tape use and increase record time.

The Model RSR 512 offers a ***512:1 speed range*** in ten binary steps. When you apply this speed range to the videocassette format, record time can vary from 50 minutes to over 426 hours, depending on the number of channels used and the bandwidths selected.

The RSR 512 is available in 8-, 16-, 24- and 32-channel configurations. More channels can be added by using an optional auxiliary housing.

The RSR 512 also features:

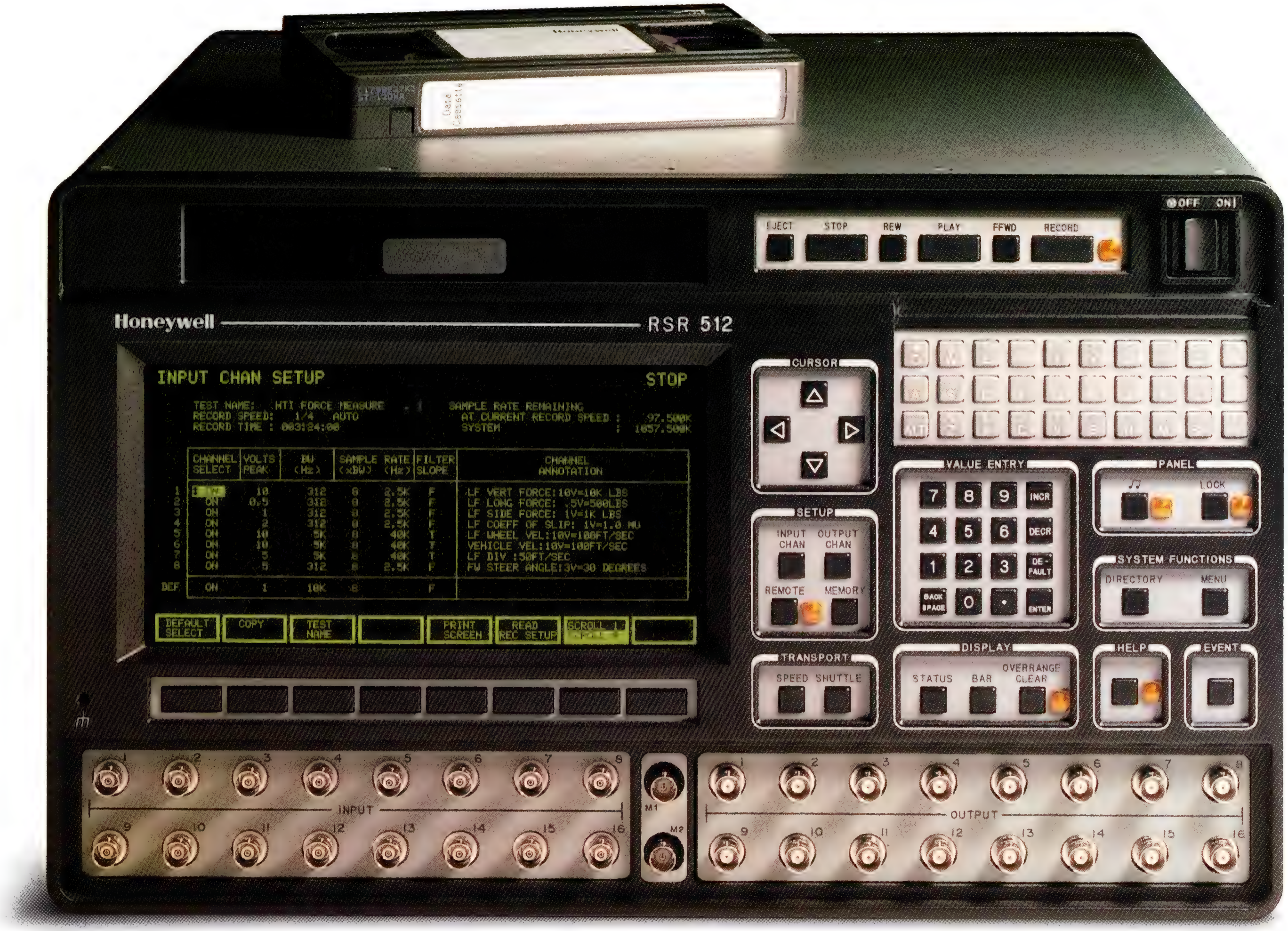
☐ ***Display/softkey.*** Displays 84 characters x 25 lines on an electroluminescent (EL) display, and offers eight softkeys for easy recorder operation.

☐ ***Tape log.*** Records administrative information on tape along with test data. ☐ ***Record and test identification.*** Assigns numbers to each individual recording, and also allows the operator to annotate tests.

☐ ***Search.*** Finds and replays data by time, number or name.

☐ ***Interval recording.*** Can be programmed to power up, record over a specified time, and power down automatically.

☐ ***Channel annotation.*** Accepts 24-character notations for each channel. ☐ ***Bar graph display.*** Displays amplitude of input



For more information on the Honeywell RSR 512,
contact Darrell Petersen at (303) 773-4835.

Honeywell

HELPING YOU CONTROL YOUR WORLD

DESIGNER'S GUIDE

precision dc
current sources
Part 3

Straightforward design adapts current sources to digital control

The first two parts of this series demonstrated how to design and analyze current sources to meet successively more demanding requirements. This final installment shows how to control current sources digitally. It also explains why the last component you want to use as a digitally controlled current source is the first one you're likely to think of—a current-output D/A converter. By adding a couple of op amps, you can change this picture completely.

Jerald Graeme, *Burr-Brown Corp*

Potentiometer-controlled current references don't measure up in automated-test applications because you must adjust them yourself. Automated measurements require digital control for the rapid setting of current levels.

This article presents three digitally controlled current-reference circuits: One uses a multiplexer, the second uses a programmable-gain amplifier, and the third uses a digital-to-analog converter. Of the three, the multiplexer approach offers the lowest parts cost but requires extensive resistor trimming. Programmable-gain amplifiers provide pretrimmed dc accuracy but are relatively slow due to phase-compensation requirements. DAC control of the output current achieves both pretrimmed accuracy and fast switching in a digitally controlled current reference.

Analog
TECHNOLOGY

In **Fig 1**'s circuit, a multiplexer and a resistor network, R_1 through R_7, replace the potentiometer of the manually adjustable, bipolar current source in Part 2 of this series. The multiplexer-based circuit retains bipolar control of the output current but provides discrete output levels instead of a continuously variable output. To simulate potentiometer action, the multiplexer connects op amp A_1's noninverting input to the resistor string's taps. Seven series resistors and the HI508A multiplexer, IC_1, deliver eight current levels with amplitudes and polarities that the resistor ratios define.

The analysis of this circuit is the same as that for the manually adjustable source. The case where load $Z_L = 0$ establishes virtual grounds and determines the output current levels. For the resistances in **Fig 1**, the reference's current levels range from −1 mA to +1 mA in 0.25-mA steps that skip zero. This set of output values requires network resistors whose values—except for that of the middle resistor, R_4—are equal. Making this resistor's value twice as great as that of the others skips the step at zero and permits four current levels for each polarity.

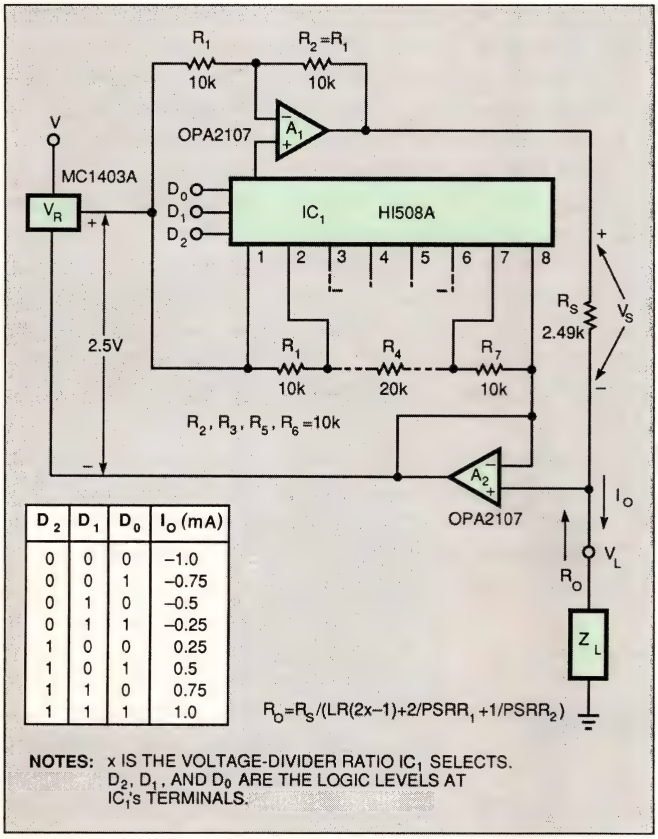
The accuracy of the resulting currents depends on compensating the tolerance errors as described for the aforementioned manually adjustable source. With 1%

Trimming individual currents for higher accuracy involves adjustments that interact, so the best practice is to simply trim each resistor to its ideal value.

network resistors, the voltage division at each tap departs by no more than 2% from the ideal. Trimming the individual currents for higher accuracy involves adjustments that interact, so the best practice is to simply trim each resistor to its ideal value. This trimming approach reduces the resistor errors to below the limit of accuracy established by drift. This limit is 50% greater than that of the manually adjustable circuit because the thick-film resistor network, according to its specs, lacks the inherent matching of the other circuit's potentiometer segments. The network uses 50-ppm/°C resistors, so, in theory, the ratio at any tap can drift by as much as 100 ppm/°C. In practice, most samples of the network exhibit better tracking than the spec implies. Based on the network's spec, **Fig 1**'s circuit drifts 0.03%/°C, so you can reliably trim its accuracy to 0.15%.

The multiplexer introduces a little more dc error than is present in the manually adjusted circuit, but the multiplexer's switching requirements impose a limit on the resistance levels. Connecting the multiplexer in series with an op-amp input avoids dc errors because none of the network currents flow through the multiplexer and only the amplifier's input current develops a voltage drop across the multiplexer's on-resistance. With the 4-pA input current of the OPA2107 and the 1.5-kΩ on-resistance of the HI508A multiplexer, the dc error is only 6 nV.

However, the multiplexer's input capacitance can degrade the switching speed. The shunt capacitance at the selected analog input is 25 pF to ground. This capacitance loads the selected resistor-network tap and delays the feedback's adjustment of the tap voltage. The settling time following a tap change varies with the tap setting because each tap presents a different output resistance. The highest output resistance appears at taps 4 and 5, which are on either side of R_4. For the network in **Fig 1**, the resistance reaches 18.7 kΩ. The multiplexer capacitance multiplied by the sum of this resistance and the multiplexer resistance produces a time constant of 0.5 μsec. Settling to 0.1% of the final value takes seven time constants, or 3.5 μsec. Because this settling time exceeds the 1-μsec settling time of the OPA2107 op amps, the multiplexer determines the switching time.



D_2	D_1	D_0	I_O (mA)
0	0	0	–1.0
0	0	1	–0.75
0	1	0	–0.5
0	1	1	–0.25
1	0	0	0.25
1	0	1	0.5
1	1	0	0.75
1	1	1	1.0

$R_O=R_S/(LR(2x-1)+2/PSRR_1+1/PSRR_2)$

NOTES: x IS THE VOLTAGE-DIVIDER RATIO IC_1 SELECTS. D_2, D_1, AND D_0 ARE THE LOGIC LEVELS AT IC_1's TERMINALS.

Fig 1—Replacing the potentiometer *of the bipolar current reference in Part 1 of this series with a resistor network and a multiplexer lets you digitally control the bipolar output current.*

Programmable-gain amp avoids trimming

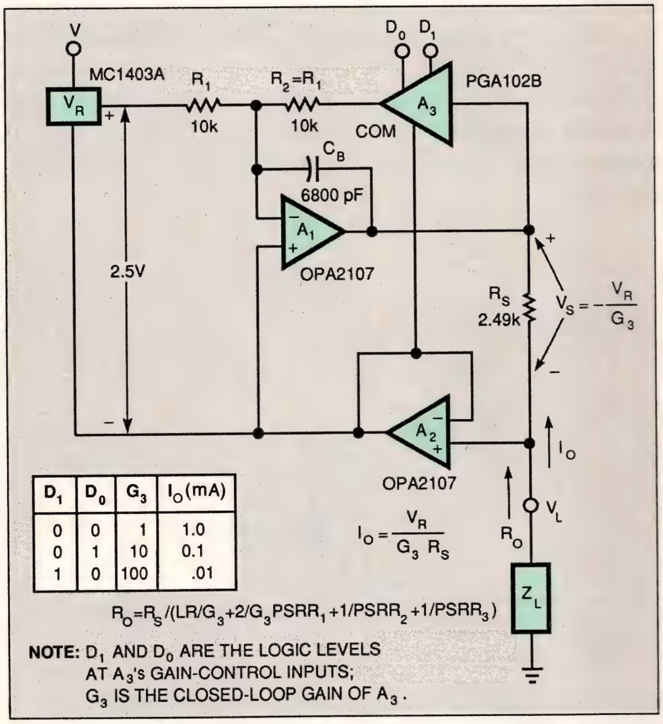
A second option for digital control employs a programmable-gain amplifier to avoid complex trimming of the current reference. Pretrimmed amplifiers let you build programmable current references with only one adjustment; you need this adjustment for final tuning, anyway. The most obvious use of programmable gain would be in amplifying the reference voltage that sets the current. However, this approach consumes too much compliance range because the amplified voltage must generally appear in series with the load. With a 2.5V reference, the gain can be no greater than five before the compliance drops to zero. At this gain, the circuit would add 12.5V in series with the load, and the amplifier output would consume at least the remaining 2.5V of a 15V power supply.

Instead, you can configure programmable-gain amplifiers as attenuators for far greater control range and little reduction in compliance. Invert the programmable-gain function to form an attenuator by connecting the programmable amplifier in the feedback loop of an op amp. As **Fig 2** shows, the gain of programmable amplifier A_3 now increases the feedback voltage instead of the voltage across sense resistor R_S. In fact, amplifying the feedback voltage reduces the voltage required across R_S and improves the current source's compliance.

Separating the basic circuit from its bootstrap signal simplifies the analysis of **Fig 2**'s circuit. The $Z_L=0$ case again permits virtual grounds at the input and output of the bootstrap amplifier, A_2. In this case, the circuit in **Fig 2** is fundamentally a voltage amplifier that consists of A_1 and A_3 and drives load resistor, R_S. The voltage amplifier develops a voltage, V_S, across R_S, which determines output current I_O.

The reference voltage, V_R, and the combined A_1-A_3 feedback determine V_S. The gain setting for A_1 is through R_1 and R_2; the equal-valued resistors in **Fig 2** set this part of the feedback gain at -1. Feedback equilibrium results when the output of A_3 presents $-V_R$ to R_2. To produce this output voltage, feedback sets the voltage at the input of A_3 and across R_S at $V_S=-V_R/G_3$. G_3 is the programmed gain of A_3. Increasing this gain reduces V_S and improves the current-source compliance. The output current is

$$I_O=V_R/(G_3R_S).$$


V
MC1403A
V_R
+
R_1
10k
$R_2=R_1$
10k
COM
D_0 D_1
A_3
PGA102B
C_B
6800 pF
A_1
OPA2107
2.5V
–
R_S
2.49k
+
$V_S=-\frac{V_R}{G_3}$
–
A_2
OPA2107
I_O
V_L
R_O
$I_O=\frac{V_R}{G_3\,R_S}$
Z_L
$R_O=R_S/(LR/G_3+2/G_3PSRR_1+1/PSRR_2+1/PSRR_3)$
NOTE: D_1 AND D_0 ARE THE LOGIC LEVELS AT A_3's GAIN-CONTROL INPUTS; G_3 IS THE CLOSED-LOOP GAIN OF A_3.

D_1	D_0	G_3	I_O(mA)
0	0	1	1.0
0	1	10	0.1
1	0	100	.01

***Fig 2—A programmable-gain amplifier** lets you digitally control current but reduces the need for resistor trimming. It improves compliance by boosting the feedback signal instead of amplifying the voltage across R_S.*

The gain (G_3) of the PGA102 programmable amplifier switches this current over a 100:1 range without increasing the compliance limitations. In **Fig 2**, gains of 1, 10, and 100 produce output currents of 1, 0.1, and 0.01 mA, respectively. As G_3 changes, the circuit alters V_S from V_R to $V_R/100$, or from 2.5V to 25 mV. Thus, V_S never limits the compliance by more than 2.5V. When $V_S=25$ mV, the circuit is more sensitive to amplifier offset voltages. The offsets of the three amplifiers combine to produce an output error current of

$$I_{ERROR}=[2V_{OS1}/G_3+(V_{OS2}+V_{OS3})]/R_S,$$

where V_{OS1}, V_{OS2}, and V_{OS3} are the offset voltages of A_1, A_2, and A_3, respectively.

Separate trims at gains of 10 and 100 minimize this output error. For $G_3=100$, the first term of the error expression is negligible. In this case, trim V_{OS2} to null the offsets of A_2 and A_3. Changing G_3 to 10 disturbs this null condition, as the first term of the error expression becomes signifigant. Offset V_{OS3} of the PGA102 changes with gain because of the amplifier's internal structure. Adjusting V_{OS1} with $G_3=10$, the second highest gain, nulls V_{OS3}. Switching G_3 to unity again changes V_{OS3}, but at this low gain, the voltage across R_S is at its maximum of 2.5V and the offset is negligible. This trim procedure reduces the offset error to less than 0.05% of the output level for all values of G_3.

Ratio adjustment simplifies trimming

The familiar dc errors from component tolerances and thermal drifts add to this offset error. The tolerance errors of the voltage reference and the three resistors are each 1%, so the initial gain error can be as large as 4%. Trimming any one of the resistors nulls this error, but adjusting R_1 and R_2 is most convenient. These two resistances have opposite effects on the output magnitude, so adjusting their ratio accommodates either polarity of initial error. A potentiometer between R_1 and R_2 with its wiper connected to A_1's inverting input lets you adjust this ratio. With this potentiometer, you can adjust the initial 4% error to less than 0.1%, at which point drift makes further trimming pointless.

As before, drifts of the error sources set the final limit on the practical trim resolution of the current reference. The four roughly equal drifts of the two op-amp offsets, the offset of A_3, and reference voltage V_R yield a temperature coefficient of 0.007%/°C. The combined effects of the temperature coefficients of the

Placing a multiplexer in series with an op-amp input avoids dc errors because the network currents don't flow through the multiplexer.

three resistors can reach 0.015%/°C for an overall 0.022%/°C sensitivity. Ambient temperature stability in typical trim and test environments limits the trim resolution to approximately 0.1%.

Other errors result from the non-ideal characteristics of the bootstrap operation that determine the current-source output resistance. Load voltage V_L changes the voltages that appear between the supply and output terminals of each of the three amplifiers and the voltage reference. As described for the first op-amp-stabilized current source in Part 1, the effect of V_L on the amplifiers is equivalent to changing the power-supply voltages.

Thus, the load voltage reacts with the amplifiers' power-supply rejection ratios (PSRRs) and the line regulation (LR) of the voltage reference. The resulting errors at the amplifier inputs equal V_L divided by the individual amplifier PSRRs. These errors reflect to R_S with the same relationships as those for the offset voltages. For the voltage reference, V_L produces a change in V_R equal to $LR \cdot V_L$. G_3 attenuates this error, which transfers to R_S. Following previous output-resistance analyses, the amplifier and reference errors combine to produce an output resistance of

$$R_O = R_S/[LR/G_3 + 2/(G_3 PSRR_1) + 1/PSRR_2 + 1/PSRR_3].$$

For the components in **Fig 2**, the line regulation dominates R_O and produces an output resistance of $20{,}000R_S$, or 50 MΩ.

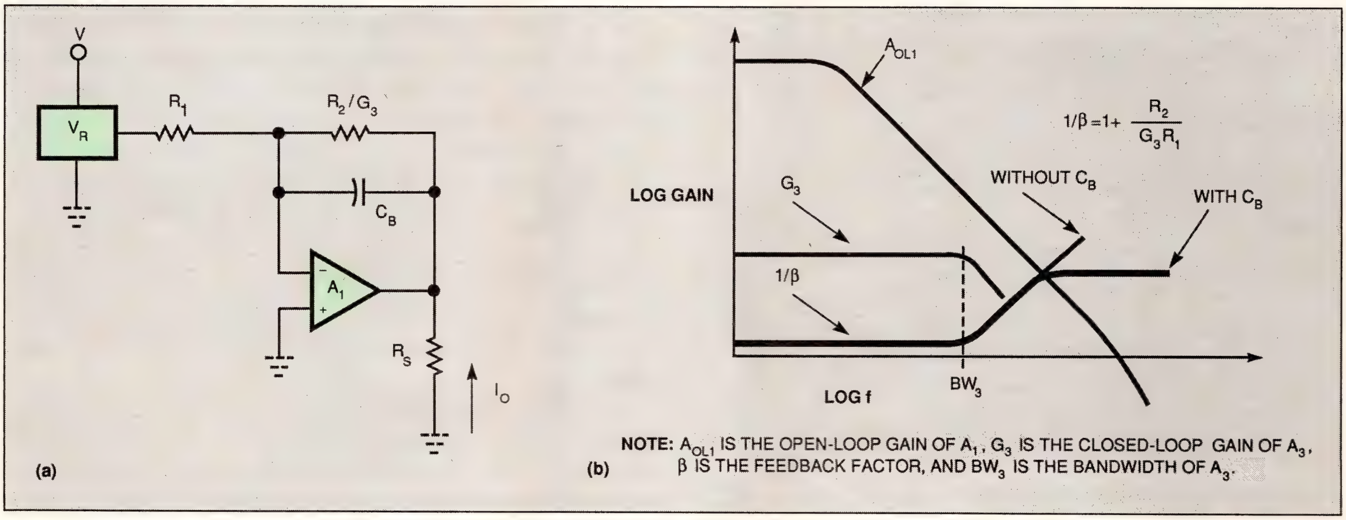
Time is also a factor in the accuracy of this digitally controlled current reference. Switching G_3 injects a voltage change through the A_1-A_3 feedback loop, and the circuit requires time to settle before it achieves its full dc accuracy. The settling time determines the required system wait after switching the reference current. Both A_1 and A_3 must adjust to the change; the phase compensation of C_B constrains their combined response.

Added phase compensation is needed to stabilize the common feedback loop of A_1 and A_3. Each of these amplifiers produces a pole in their common loop, but loop stability accommodates only one pole. To compensate the loop phase, C_B bypasses the A_3 path at high frequencies. This short circuit leaves A_1 in control of the output, and A_1's unity-gain stability ensures the stability of the common loop.

Choose compensation capacitors carefully

Feedback analysis will guide your choice of compensation capacitor C_B **(Ref 1)**. Without A_3 and C_B, the R_1/R_2 voltage divider forms the feedback network around A_1. The divider would produce a feedback factor of $R_1/(R_1+R_2)$, but G_3, the gain of A_3, modifies this factor. Amplifying the feedback signal on R_2 increases this resistor's signal current just as decreasing the resistor's value would. The effective feedback resistance of R_2 is then R_2/G_3, as **Fig 3a** shows. The dashed ground symbols represent the virtual grounds of the $Z_L=0$ analysis case. The actual feedback factor—still without C_B—is

$$\beta = R_1/[R_1 + (R_2/G_3)].$$



NOTE: A_{OL1} IS THE OPEN-LOOP GAIN OF A_1, G_3 IS THE CLOSED-LOOP GAIN OF A_3, β IS THE FEEDBACK FACTOR, AND BW_3 IS THE BANDWIDTH OF A_3.

***Fig 3—Switchable gain alters** the effective feedback resistance of **Fig 2**'s circuit **(a)**, varies the frequency response of the feedback **(b)**, and requires phase compensation of 1/β.*

To examine loop stability, plot $1/\beta$ on the open-loop-response curve of op amp A_1, as **Fig 3b** shows. Without C_B, the inverse of the feedback factor is

$$1/\beta = 1 + R_2/(G_3R_1).$$

This $1/\beta$ expression represents a line that remains horizontal until it reaches the frequency at which G_3 begins to roll off. Then, $1/\beta$ rises with a slope of 20 dB/decade and intercepts the open-loop-response curve where the latter curve has a slope of −20 dB/decade. The difference in slopes at the intercept, or the rate of closure, is 40 dB/decade, which corresponds to two poles in the loop and 180° of feedback phase shift. At the intercept, 180° of phase shift indicates oscillation.

To prevent oscillation, C_B bypasses the effective resistance R_2/G_3, which makes the $1/\beta$ curve a horizontal line at high frequencies. This phase compensation is similar to the solution for the circuit in Part 2 that uses an instrumentation amp in its feedback loop, but the variable gain of A_3 makes stabilizing the circuit of **Fig 2** more difficult. You must choose C_B to bypass R_2/G_3 for all values of G_3. Both the magnitude and the bandwidth of G_3 vary as you switch the current reference. The most demanding bypass condition occurs for the maximum value of G_3. In this case, the low-frequency value of R_2/G_3 is at its lowest, so the $1/\beta$ curve starts at its lowest level. Also, when G_3 is at its maximum, A_3's bandwidth, BW_3, is lowest. This gain-bandwidth combination leads to a broad frequency interval where the $1/\beta$ curve rises prior to intercepting the A_{OL1} curve.

Such a $1/\beta$ curve signals large added phase shift for the loop, and this added phase shift typically requires compensation. Following the solution for the 2-amplifier loop in Part 2 of this series, choose C_B to break with R_2/G_3 at the intercept of the $1/\beta$ curve and A_1's open-loop gain response. As before, this $1/\beta$ pole provides 45° of phase margin and the location of the compensation pole determines the required value of C_B.

The necessity of choosing C_B for the maximum G_3 gain produces excess phase compensation for lower gain levels and relatively slow settling times. At the maximum gain, with $G_3 = 100$ and $BW_3 = 250$ kHz, the 6800-pF value of C_B correctly compensates the OPA2107-PGA102 common loop. The settling time following a switch in the reference current is 10 μsec. For lower gains, the effective resistance of R_2/G_3 is greater and the C_B bypass drops the bandwidth of the common loop correspondingly. Settling time increases in proportion to the bandwidth reduction and becomes 100 μsec for $G_3 = 10$ and 1 msec for $G_3 = 1$.

In automated test systems, this settling time is still preferable to inconvenient manual control, but throughput requirements often dictate a faster solution. In such cases, using a DAC in a current reference offers high-speed switching and high-resolution control of the output current. An obvious but inaccurate option for such a current reference is a current-output DAC, as **Fig 4a** shows.

This current reference supplies a current under digital control and offers a broad selection of output levels. However, DACs operated with current output have low output resistance and poor absolute accuracy. They easily lose accuracy when their output currents develop voltage on a load resistance. With an output resistance of only about 4 kΩ, a 12-bit current-output DAC produces a current that declines by the equivalent of ½ LSB for every 0.5Ω increase in load resistance. Such DACs often have a voltage compliance of only 1V for at least one polarity of output. With such load sensitivity, a current-output DAC is little more than a DAC counterpart of the elemental voltage-to-current converter that began this series.

Actually, most current-output DACs use external op amps to develop voltage outputs. These DACs include current-to-voltage (I/V) conversion resistors, which are critical to their accuracy. When you connect the output of such a DAC to an op-amp summing junction and connect the I/V resistor between the summing junction and the op amp's output, you obtain an output voltage that is nearly independent of the DAC's output resistance. The I/V resistor ratio-matches and thermally tracks the DAC's internal current-setting resistors. The accuracy of the output voltage depends on this matching and tracking; ideally, the output voltage is a function only of the DAC's digital input and reference voltage.

Current-output DACs are poor current sources

If, instead, you use the DAC's output current directly, the output becomes a function of absolute resistor values rather than of ratios. The output error can be as great as ±20%. Even if you somehow compensate for this initial error, the output current suffers from thermal drift. Given the typical resistance temperature coefficient of 50 ppm/°C, the current output of a 12-bit DAC has a drift of ¼ LSB/°C. This temperature sensitivity combined with a DAC's high initial tolerance and low output resistance make the current output of a DAC unusable for most current-reference applications.

Pretrimmed programmable-gain amplifiers let you build programmable current references that have only one adjustment.

To form an accurate current reference with a DAC, obtain the DAC's output in the form of a ground-referenced voltage. Then, use a voltage-to-current (V/I) converter to convert the DAC output voltage to a current. You must use a V/I converter that accepts ground-referenced inputs because, in nearly all cases, the digital signals that drive the DAC will be referenced to ground and the DAC itself provides no isolation between its input and output ground references. In addition, the load voltage must not affect the V/I conversion, and the current output should have a compliance equal to a substantial portion of the supply voltage. With 15V power supplies and a DAC whose full-scale output voltage is 10V, the last constraint suggests using a V/I converter whose maximum sense-resistor voltage is a small fraction of the input voltage.

The circuit in Part 2 that takes feedback through an instrumentation amplifier also accepts a ground-referred reference voltage and drives a grounded load. **Fig 4b** shows that circuit modified to work with a DAC. From its ground-referred output, the DAC impresses its full voltage, V_{DAC}, at the input of A_1; feedback forces the same voltage at the output of A_2. G_2, the gain of instrumentation amp A_2, buffers the current-sense resistor, R_S, from the full DAC output. To satisfy the feedback loop, the voltage across R_S is only V_{DAC}/G_2. Making $G_2=10$ reduces the current-sense voltage to 1V when the maximum value of V_{DAC} is 10V.

In **Fig 4b**, the DAC permits a broad range of output current levels. With R_S at 100Ω, control of the DAC output produces currents ranging from 2.44 μA to 10 mA in 4096 steps. Alternately, the DAC811 can operate in its bipolar output mode and produce currents ranging from −10 mA to +10 mA in 4.88-μA steps. To accurately resolve these small step sizes, trim the offset voltages of the DAC and the amplifiers. These offsets produce an output current error of

$$I_{ERROR} = [(V_{OSD} + V_{OS1})/G_2 + V_{OS2}]/R_S,$$

where V_{OSD} is the offset voltage of the DAC. Offset trimming reduces the dc output error to 0.2 μA, or about 1/10 LSB.

Gain error depends on the accuracy of the DAC and the tolerance of R_S. The initial DAC gain error is 0.1%; choosing a precision resistor for R_S reduces the resistor tolerance to 0.1% as well. The DAC's gain-trim provision lets you reduce the combined 0.2% error to below 0.01%, at which point thermal drifts make further trimming a waste of time. The DAC's gain drift is 10 ppm/°C. Choosing R_S for an equal temperature coefficient

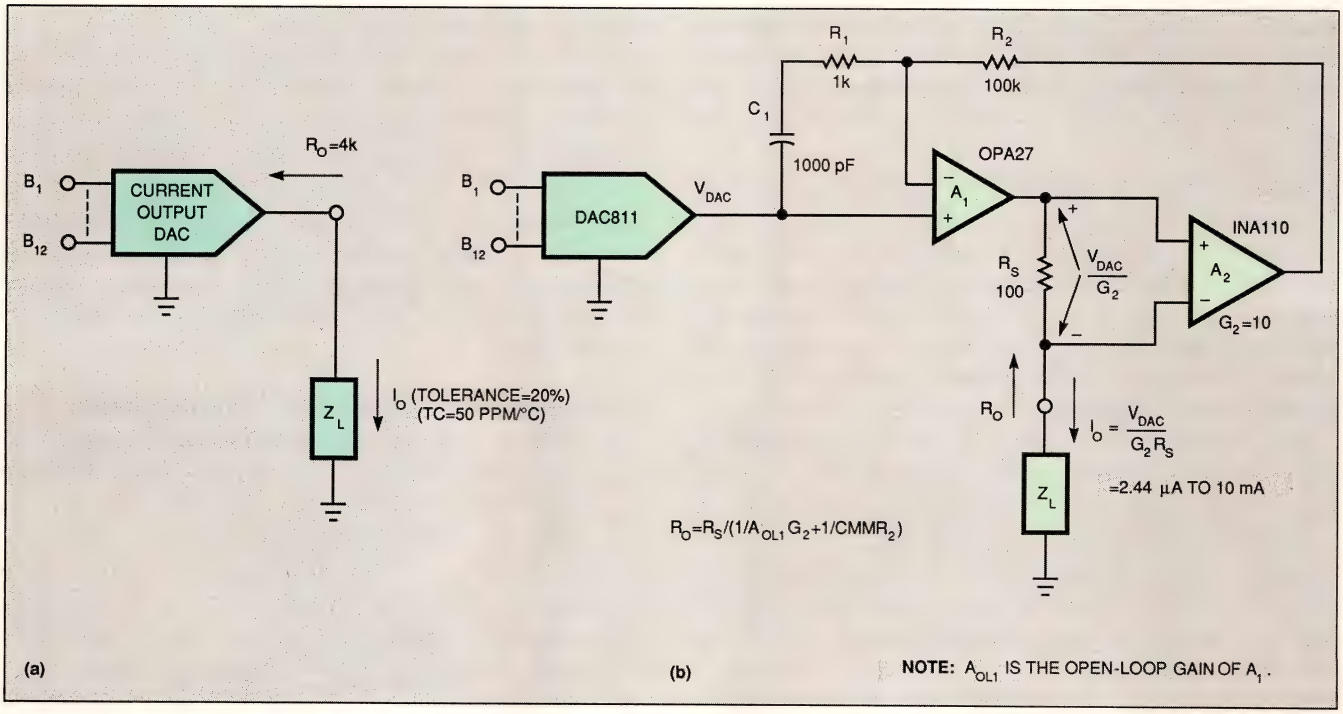
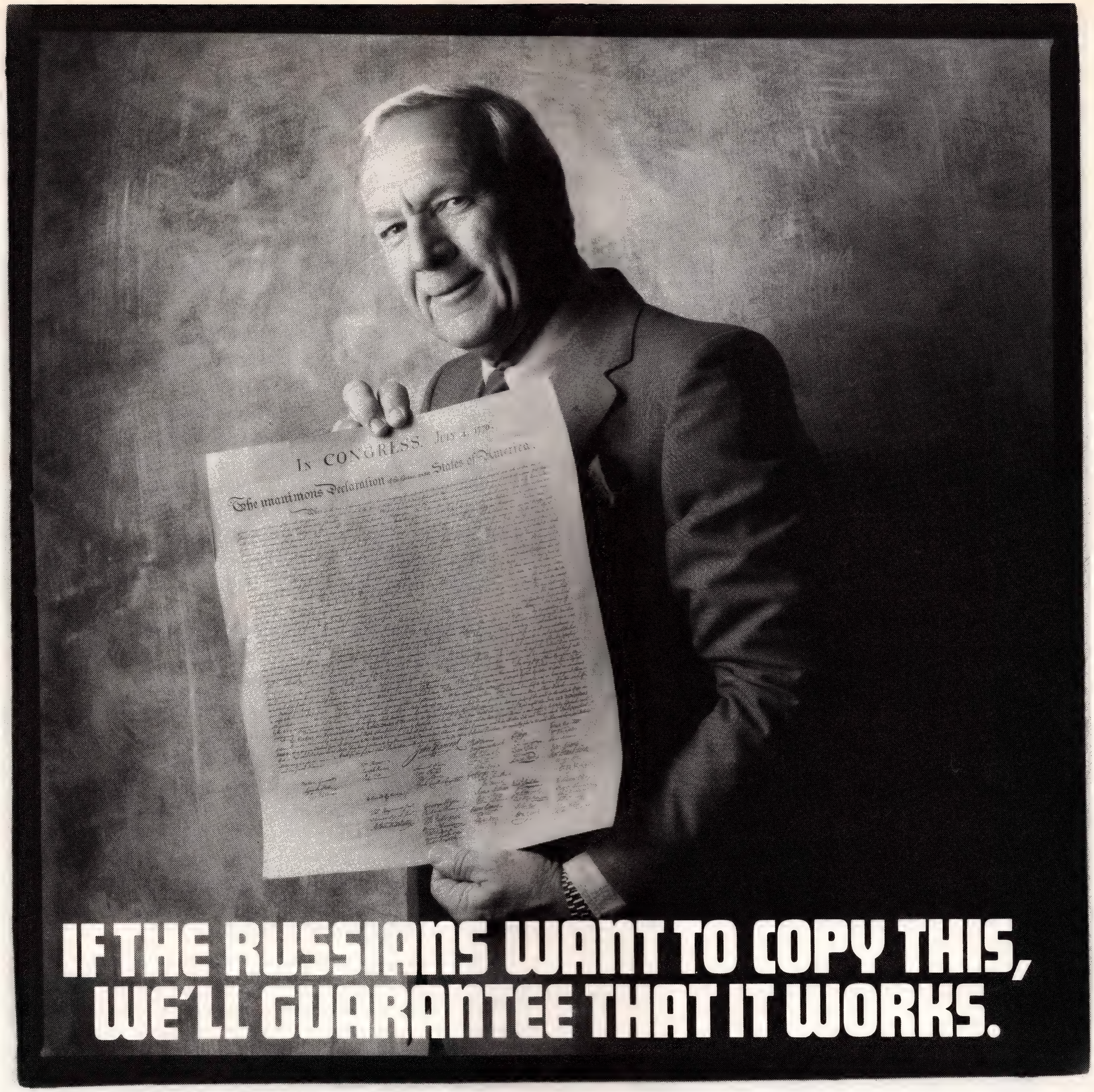


***Fig 4—As a current reference,** a DAC lacks precision in the current-output mode **(a)** but recovers accuracy in the voltage-output mode **(b)**. (This circuit is a modification of the circuit that uses an instrumentation amp in Part 2 of this series.)*


IF THE RUSSIANS WANT TO COPY THIS,
WE'LL GUARANTEE THAT IT WORKS.

To ensure life, liberty and the pursuit of happiness in your office, we'd like to propose a system that's guaranteed to work. The Lanier copier system. Lanier copiers are guaranteed to be up and running 98% of the time. You get a loaner for the times it's not. And you get a 24-hour toll-free Hot Line for any questions you have. So for more productivity, call **1-800-852-2679**. And make a declaration that you want the very best copier system in the USA. Lanier.

LANIER
COPYING SYSTEMS

HARRIS

CIRCLE NO. 71

Some restrictions apply. See your local Lanier copier representative for full details.

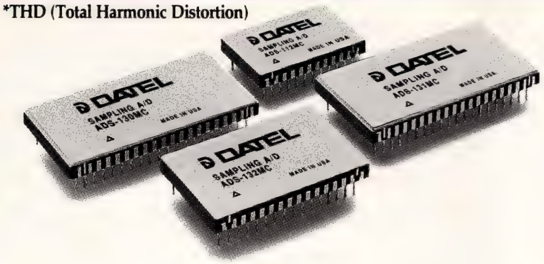
Sampling A/Ds

DATEL's video speed 12-bit sampling A/D converters give superior dynamic performance, to bring both harmonic distortion and signal-to-noise ratios to new lows.

For complete information call (508) 339-3000

Model	Sampling Rate	Effective Bits at Nyquist Frequency	THD* at Nyquist Frequency	Power Dissipation	Package	Price (1-9)
ADS-112	1MHz	11.0	-73 dB	1.3 watts	24-pin DDIP	$259
ADS-132	2MHz	11.0	-73 dB	2.9 watts	32-pin TDIP	$346
ADS-131	5MHz	10.6	-69 dB	4.2 watts	40-pin TDIP	$549
ADS-130	10MHz	10.6	-69 dB	4.5 watts	40-pin TDIP	$775

*THD (Total Harmonic Distortion)



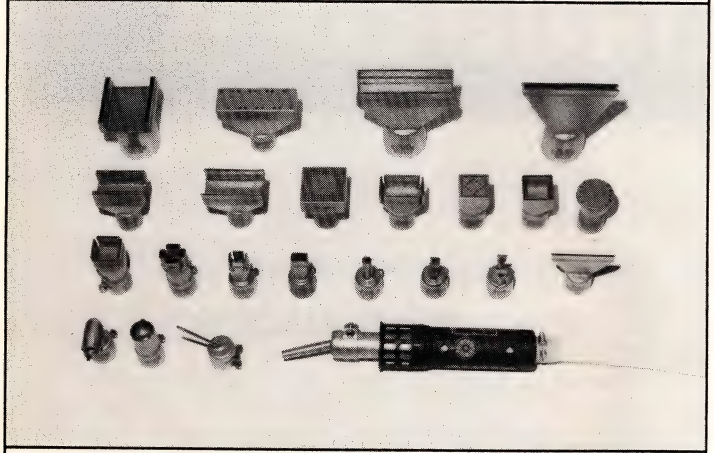
DATEL

INNOVATION AND EXCELLENCE IN PRECISION DATA ACQUISITION
DATEL, Inc., 11 Cabot Boulevard, Mansfield, MA 02048 (508) 339-3000

CIRCLE NO. 7

Contact-free soldering and de-soldering

of SMD, DIP and pin grid components and connectors in a matter of seconds with the Leister-Labor "S" hot-air tool. Electronic control of temperature and air supply. Over 400 special nozzles available.



Ask for free brochure UW 175

Brian R. White Co. Inc., 313 Henry Station Road
Ukiah, CA 95482 phone: (707) 462-9795
Farmingdale, NJ 07727 phone: (201) 938-2700

CIRCLE NO. 8

produces a total drift of 20 ppm/°C, so the temperature variations of a lab environment would change the gain by no more than 100 ppm.

The output-resistance error is negligible for each of the previous circuits but becomes significant with the high precision of the circuit in **Fig 4b.** The output resistance, R_O, is most significant with a large load resistance. From the discussion in Part 2, the voltage-to-current converter in **Fig 4b** has $R_O=200{,}000R_S=20$ MΩ. With 15V supplies, the compliance is 11V. This compliance and the circuit's 10-mA full-scale output accommodate load resistances as large as 1.1 kΩ. With $R_O=20$ MΩ and load resistance $R_L=1.1$ kΩ, the output resistance error is 55 ppm, or about ¼ LSB.

DAC-based current sources are fast, too

The settling time of the circuit in **Fig 4b** is far better than that of the circuit in **Fig 2** because phase compensation is simpler. Both circuits have a 2-amplifier feedback loop, but in **Fig 4b,** the loop gain remains constant. In **Fig 2,** switching varies the gain by a factor of 100:1, and at the lowest gain, phase compensation is excessive by the same factor. In **Fig 4b,** only one loop-gain condition determines frequency stability; the circuit does not need excess phase compensation. With the OPA27 and INA110, the settling time is 50 µsec for a full-scale transition as compared with the 1-msec worst case of the circuit in **Fig 2.**

In addition to presenting a variety of voltage-reference-based current references, this series has demonstrated analytical techniques that enable you to calculate the accuracy of any such circuit and to predict its dynamic characteristics. These analytical approaches work with other analog circuits, so studying these examples should help you become more proficient with all types of analog design. **EDN**

Reference

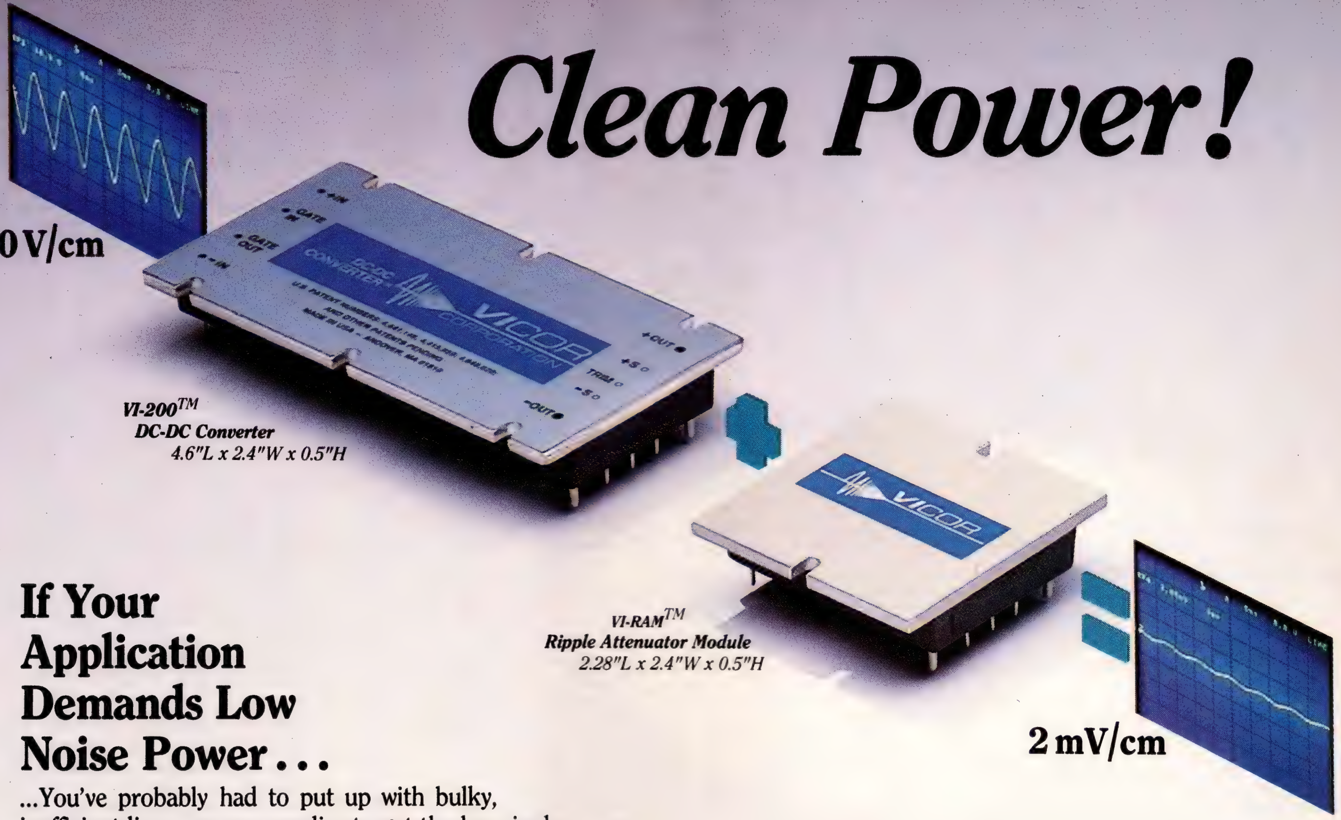
1. Graeme, J, "Feedback plots offer insight into operational amplifiers," *EDN*, January 19, 1989, pg 131.

Author's biography

For Jerald Graeme's biography, see Part 1 of this series in EDN, April 12, 1990, pg 198.

Article Interest Quotient (Circle One)
High 491 Medium 492 Low 493

Clean Power!



VI-200™ DC-DC Converter 4.6"L x 2.4"W x 0.5"H

VI-RAM™ Ripple Attenuator Module 2.28"L x 2.4"W x 0.5"H

If Your Application Demands Low Noise Power . . .

...You've probably had to put up with bulky, inefficient linear power supplies to get the low ripple that wide-dynamic-range signal conditioning applications demand. In test and measurement, medical imaging, quality audio, RF, or other demanding applications, even the best switchmode power supplies haven't been able to deliver the combination of line harmonic rejection and low switching noise that your system demands. If you've ever wished for the noise performance of a linear in the space of a switcher, then...

Vicor Has The Solution...

Our high-frequency conversion architecture redefined the state-of-the-art in terms of power density and efficiency. Now we're introducing the **Ripple Attenuator Module**™, a modular companion to our family of VI-200 converters which offers the noise performance of a linear while achieving power densities up to 23 Watts/cubic inch!

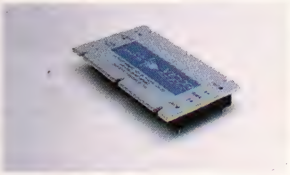
Add a **Ripple Attenuator Module**™ to any Vicor VI-200™ converter, MegaModule™, MasterModule™ or FlatPAC™ with output voltages from 5 to 50 Volts and limit total output noise to less than **2mV, peak-to-peak** at loads up to 10 Amps. Combining active and passive filtering, RAMs attenuate both low frequency line harmonics and high frequency switching components in the range of DC to 20 MHz...by approximately 40 dB. No adjustments are required, and remote sense and output voltage trim features are retained.

RAMs Are Available In Three Product Grades:

■ Commercial	0°C to +85°C	VI-RAM-C1
■ Industrial	−40°C to +85°C	VI-RAM-I1
■ Military	−55°C to +100°C	VI-RAM-M1

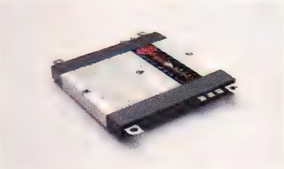
VI-RAMs Are Designed For Use With The Following Products:

VI-200™ Series *DC-DC Converters and Power Boosters™*



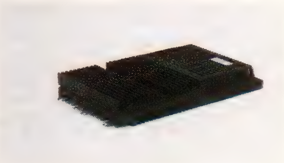
- 12 to 300 VDC nom. inputs
- Single output, 2-95 Volts
- 50, 75, 100, 150, 200 Watts
- Up to 36 Watts/cubic inch
- UL, CSA, TUV

Mega/Master Module™ Series *High Power DC-DC Converters*



- 12 to 300 VDC nom. inputs
- Single, dual and triple output
- Up to 600 Watts
- Up to 27 Watts/cubic inch
- UL, CSA, TUV

FlatPAC™ Series *High Power AC-DC Switchers*



- 115/230 VAC strappable
- Single, dual and triple output
- Up to 600 Watts
- Up to 7 Watts/cubic inch
- UL, CSA, TUV

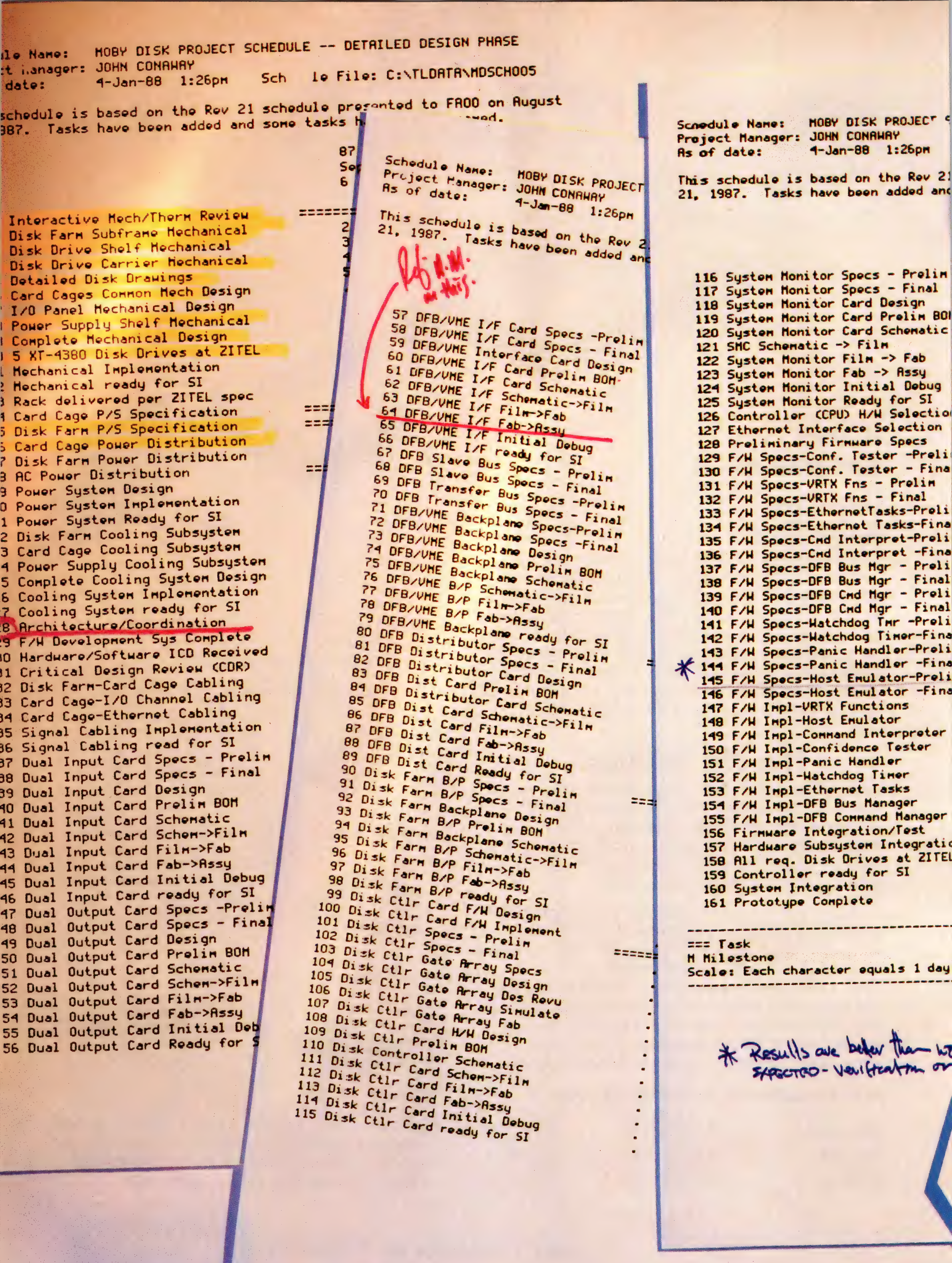
If you'd like to try a VI-RAM, or want to know more about our complete family of component-level power products, call Vicor today at (800) 735-6200. For immediate delivery of Vicor products ask for Vicor Express at Ext. 265.

Component Solutions For Your Power System

VICOR

Common Stock traded on NASDAQ under **"VICR"**

CIRCLE NO. 72



```
le Name:    MOBY DISK PROJECT SCHEDULE -- DETAILED DESIGN PHASE
t Manager: JOHN CONAWAY
 date:      4-Jan-88  1:26pm    Sch   le File: C:\TLDATA\MDSCH005

schedule is based on the Rev 21 schedule presented to FAOO on August
387.  Tasks have been added and some tasks h                    ned.

                                                      87
                                                      Se
                                                      6

 Interactive Mech/Therm Review                   =======
 Disk Farm Subframe Mechanical                         2
 Disk Drive Shelf Mechanical                           3
 Disk Drive Carrier Mechanical                         4
 Detailed Disk Drawings                                5
 Card Cages Common Mech Design
 I/O Panel Mechanical Design
 Power Supply Shelf Mechanical
 Complete Mechanical Design
 5 XT-4380 Disk Drives at ZITEL
1 Mechanical Implementation
2 Mechanical ready for SI
3 Rack delivered per ZITEL spec
4 Card Cage P/S Specification                     ===
5 Disk Farm P/S Specification                     ===
6 Card Cage Power Distribution
7 Disk Farm Power Distribution
8 AC Power Distribution                            ==
9 Power System Design
0 Power System Implementation
1 Power System Ready for SI
2 Disk Farm Cooling Subsystem
3 Card Cage Cooling Subsystem
4 Power Supply Cooling Subsystem
5 Complete Cooling System Design
6 Cooling System Implementation
7 Cooling System ready for SI
8 Architecture/Coordination
9 F/W Development Sys Complete
30 Hardware/Software ICD Received
31 Critical Design Review (CDR)
32 Disk Farm-Card Cage Cabling
33 Card Cage-I/O Channel Cabling
34 Card Cage-Ethernet Cabling
35 Signal Cabling Implementation
36 Signal Cabling read for SI
37 Dual Input Card Specs - Prelim
38 Dual Input Card Specs - Final
39 Dual Input Card Design
40 Dual Input Card Prelim BOM
41 Dual Input Card Schematic
42 Dual Input Card Schem->Film
43 Dual Input Card Film->Fab
44 Dual Input Card Fab->Assy
45 Dual Input Card Initial Debug
46 Dual Input Card ready for SI
47 Dual Output Card Specs -Prelim
48 Dual Output Card Specs - Final
49 Dual Output Card Design
50 Dual Output Card Prelim BOM
51 Dual Output Card Schematic
52 Dual Output Card Schem->Film
53 Dual Output Card Film->Fab
54 Dual Output Card Fab->Assy
55 Dual Output Card Initial Deb
56 Dual Output Card Ready for S
```

```
Schedule Name:    MOBY DISK PROJECT
Project Manager: JOHN CONAWAY
As of date:       4-Jan-88  1:26pm

This schedule is based on the Rev 2
21, 1987.  Tasks have been added and
```

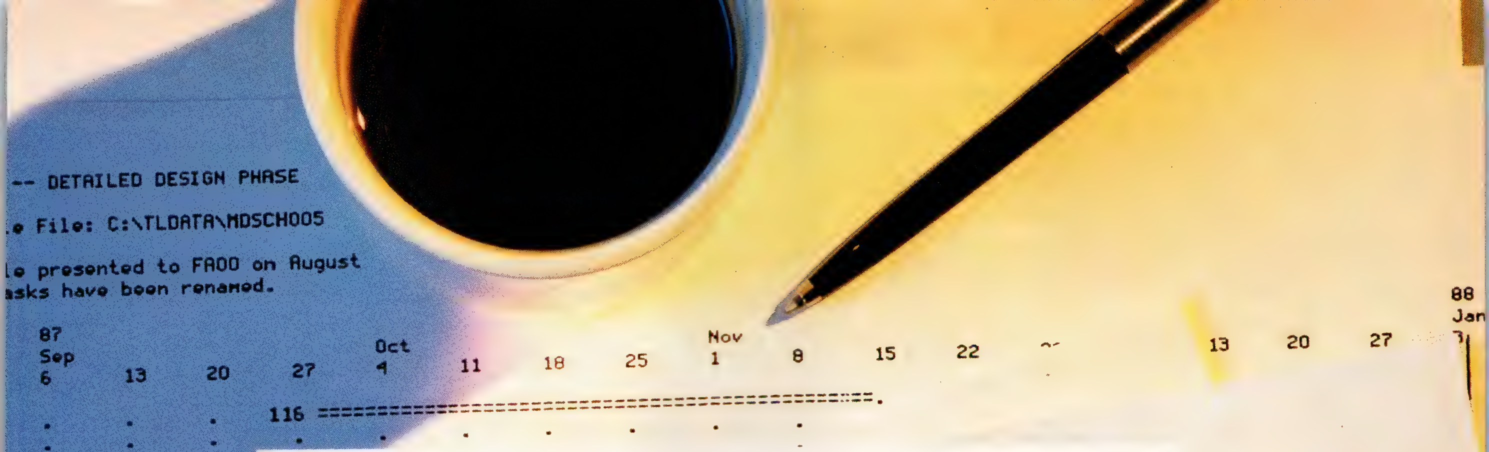
Ref. A.M. on this.

```
 57 DFB/VME I/F Card Specs -Prelim
 58 DFB/VME I/F Card Specs - Final
 59 DFB/VME Interface Card Design
 60 DFB/VME I/F Card Prelim BOM
 61 DFB/VME I/F Card Schematic
 62 DFB/VME I/F Schematic->Film
 63 DFB/VME I/F Film->Fab
 64 DFB/VME I/F Fab->Assy
 65 DFB/VME I/F Initial Debug
 66 DFB/VME I/F ready for SI
 67 DFB Slave Bus Specs - Prelim
 68 DFB Slave Bus Specs - Final
 69 DFB Transfer Bus Specs -Prelim
 70 DFB Transfer Bus Specs - Final
 71 DFB/VME Backplane Specs-Prelim
 72 DFB/VME Backplane Specs -Final
 73 DFB/VME Backplane Design
 74 DFB/VME Backplane Prelim BOM
 75 DFB/VME Backplane Schematic
 76 DFB/VME B/P Schematic->Film
 77 DFB/VME B/P Film->Fab
 78 DFB/VME B/P Fab->Assy
 79 DFB/VME Backplane ready for SI
 80 DFB Distributor Specs - Prelim
 81 DFB Distributor Specs - Final
 82 DFB Distributor Card Design              =
 83 DFB Dist Card Prelim BOM
 84 DFB Distributor Card Schematic
 85 DFB Dist Card Schematic->Film
 86 DFB Dist Card Film->Fab
 87 DFB Dist Card Fab->Assy
 88 DFB Dist Card Initial Debug
 89 DFB Dist Card Ready for SI
 90 Disk Farm B/P Specs - Prelim
 91 Disk Farm B/P Specs - Final              ===
 92 Disk Farm Backplane Design
 93 Disk Farm B/P Prelim BOM
 94 Disk Farm Backplane Schematic
 95 Disk Farm B/P Schematic->Film
 96 Disk Farm B/P Film->Fab
 97 Disk Farm B/P Fab->Assy
 98 Disk Farm B/P ready for SI
 99 Disk Ctlr Card F/W Design
100 Disk Ctlr Card F/W Implement
101 Disk Ctlr Specs - Prelim
102 Disk Ctlr Specs - Final                  ======
103 Disk Ctlr Gate Array Specs
104 Disk Ctlr Gate Array Design
105 Disk Ctlr Gate Array Des Revu
106 Disk Ctlr Gate Array Simulate
107 Disk Ctlr Gate Array Fab
108 Disk Ctlr Card H/W Design
109 Disk Ctlr Prelim BOM
110 Disk Controller Schematic
111 Disk Ctlr Card Schem->Film
112 Disk Ctlr Card Film->Fab
113 Disk Ctlr Card Fab->Assy
114 Disk Ctlr Card Initial Debug
115 Disk Ctlr Card ready for SI
```

```
Schedule Name:    MOBY DISK PROJEC
Project Manager: JOHN CONAWAY
As of date:       4-Jan-88  1:26pm

This schedule is based on the Rev 2
21, 1987.  Tasks have been added and

  116 System Monitor Specs - Prelim
  117 System Monitor Specs - Final
  118 System Monitor Card Design
  119 System Monitor Card Prelim BO
  120 System Monitor Card Schematic
  121 SMC Schematic -> Film
  122 System Monitor Film -> Fab
  123 System Monitor Fab -> Assy
  124 System Monitor Initial Debug
  125 System Monitor Ready for SI
  126 Controller (CPU) H/W Selectio
  127 Ethernet Interface Selection
  128 Preliminary Firmware Specs
  129 F/W Specs-Conf. Tester -Preli
  130 F/W Specs-Conf. Tester - Fina
  131 F/W Specs-VRTX Fns - Prelim
  132 F/W Specs-VRTX Fns - Final
  133 F/W Specs-EthernetTasks-Preli
  134 F/W Specs-Ethernet Tasks-Fina
  135 F/W Specs-Cmd Interpret-Preli
  136 F/W Specs-Cmd Interpret -Fina
  137 F/W Specs-DFB Bus Mgr - Preli
  138 F/W Specs-DFB Bus Mgr - Final
  139 F/W Specs-DFB Cmd Mgr - Preli
  140 F/W Specs-DFB Cmd Mgr - Final
  141 F/W Specs-Watchdog Tmr -Preli
  142 F/W Specs-Watchdog Timer-Fina
  143 F/W Specs-Panic Handler-Preli
* 144 F/W Specs-Panic Handler -Fina
  145 F/W Specs-Host Emulator-Preli
  146 F/W Specs-Host Emulator -Fina
  147 F/W Impl-VRTX Functions
  148 F/W Impl-Host Emulator
  149 F/W Impl-Command Interpreter
  150 F/W Impl-Confidence Tester
  151 F/W Impl-Panic Handler
  152 F/W Impl-Watchdog Timer
  153 F/W Impl-Ethernet Tasks
  154 F/W Impl-DFB Bus Manager
  155 F/W Impl-DFB Command Manager
  156 Firmware Integration/Test
  157 Hardware Subsystem Integratio
  158 All req. Disk Drives at ZITEL
  159 Controller ready for SI
  160 System Integration
  161 Prototype Complete

 ------------------------------------
 === Task
 M Milestone
 Scale: Each character equals 1 day
 ------------------------------------
```

* Results are better than
EXPECTED - verification or

Zitel is a public company traded on the NASDAQ National Market System under the symbol ZITL.



AT ZITEL, WE NEVER LET TOUGH PROJECTS GET THE BEST OF YOU.

So you've got to design, build and bring to market a high performance memory product for your company. And you need it yesterday.

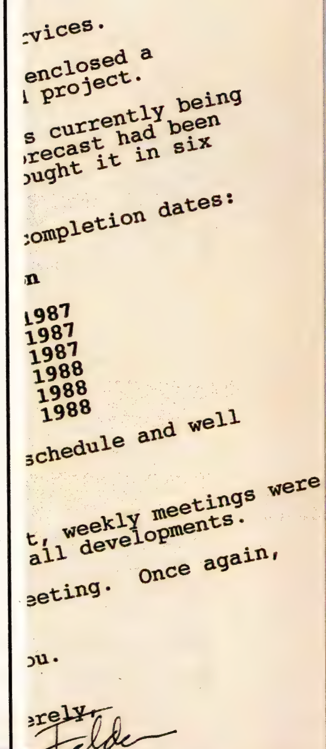
Now there's an easy solution: Call Zitel.

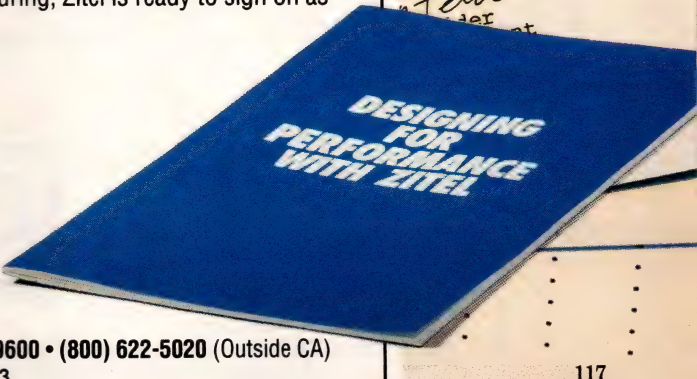
We've been designing and building fast, reliable memory solutions for defense, medical and satellite imaging, flight and radar simulation and geoseismic exploration for over 10 years. Our team will provide you with the solution you need. On time and on budget.

A case in point: Moby Disk, shown in this ad. It took 161 steps to take this 20 Gigabyte, 24 I/O channel 30 MByte/second 40 disk array from customer specification to first item delivery.

Moby Disk was delivered and installed in 13 months – 5 months ahead of schedule. And it was right the first time.

Call 1-800-622-5020 for complete information on the Zitel Task Management program and a free booklet, "Designing for Performance with Zitel." From custom design, to system integration, to high quality manufacturing, Zitel is ready to sign on as your partner.


rvices.
enclosed a
project.
s currently being
recast had been
ought it in six
completion dates:
n
1987
1987
1987
1988
1988
1988
schedule and well
t, weekly meetings were
all developments.
eeting. Once again,
ou.
erely,



zitel®

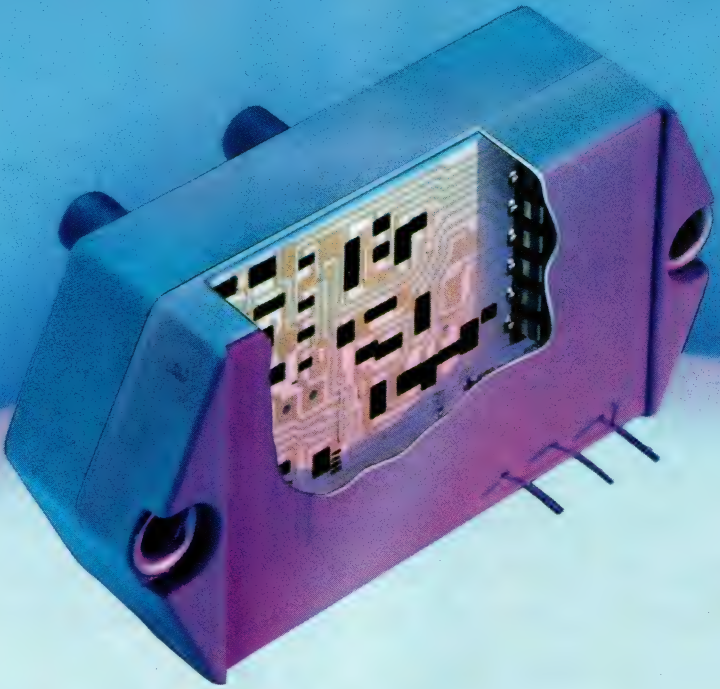
Memories of the future

630 Alder Drive • Milpitas, CA 95035 • **(408) 946-9600** • **(800) 622-5020** (Outside CA)

CIRCLE NO. 73

HAWKER

Advanced Pressure Sensors



FOR:
MEDICAL
INDUSTRIAL
HVAC

Sensym's 142/163 Series

Features Include:

- Guaranteed precision over temperature: ±1% Max (−18°C to +63°C)!
- High level calibrated output: 1.0V ±50mV offset 5.0V ±50mV span
- Linearity: <0.75% FSO Max

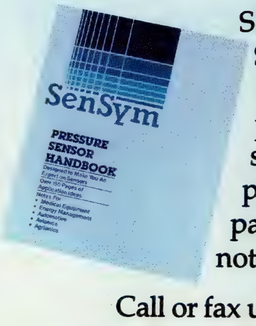
These precision transducers are priced starting at **$40 ea/100's. Stock delivery.**

Available parts:

163SC01D48	−20 to +120 cmH_2O
142SC series	0 to 1psi up to 0 to 150 psi

HAWKER SenSym SIDDELEY
SOLID STATE SENSORS

Free Handbook



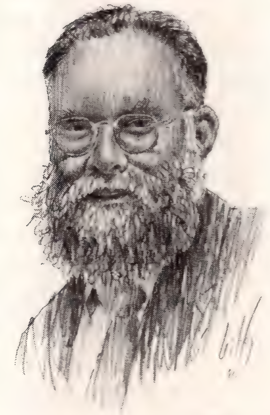
Sensym's new 1990 Sensor Handbook gives complete product specifications plus over 200 pages of application notes and ideas.

Call or fax us today for your free Sensor Handbook.

CIRCLE NO. 74

1244 Reamwood Avenue ■ Sunnyvale, CA 94089 ■ Tel: (408) 744-1500 ■ Fax: (408) 734-0407

Pease's pointers rouse readers:



Letters to Bob

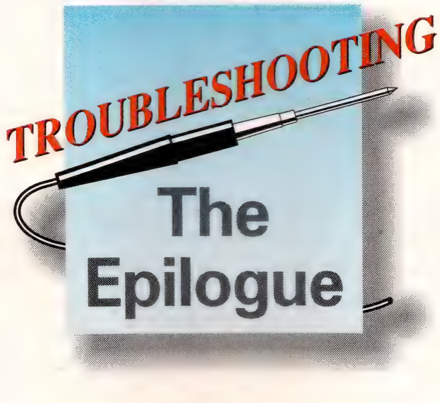
Bob Pease's series on troubleshooting generated myriad letters from readers—far more than we could do justice to in our Signals and Noise column. Because so many of the letters contained worthwhile troubleshooting tips and amusing personal anecdotes, EDN's editors decided to collect some of the best letters into an article, along with Bob's replies and interjections. (Turn to the last page of this article for a list of the issues that contain the 12-part "Troubleshooting Analog Circuits" series.)

The tips just keep on coming

Dear Bob:

Here are some tips and gotchas:

1. A significant source of noise in my lab is the ever-present video-display terminal. It couples especially well to audio-frequency transformers.



2. I head off a lot of trouble by providing RF bypass on audio and dc circuits. Their audio and low-frequency-only inputs can pick up AM radio. Having music come out of a speaker that is supposed to be a monitor on a telephone circuit is very bad form.

3. My computer brethren frequently fail to consider what happens during reset. I saw a thermal printer catch on fire once when its internal μP was reset. The reset 3-stated the print head's drivers, which allowed all of them to turn on continuously. Later a software bug turned them on continuously again. I finally made the print head computer-proof by capacitively coupling the drivers so that the μP had to produce a continuous sequence of pulses to keep the heads turned on.

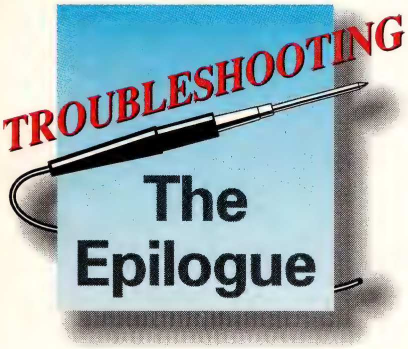
4. My inexperienced brethren frequently forget to calculate total power-supply requirements.

5. Vishay (Malvern, PA) produces some very accurate, very stable (0.6 ppm/°C) resistors, which I keep around to check ohmmeters.

6. Some companies think they are helping designers by taking instruments to the calibration lab without

letting the designers know. They do not understand that small day-to-day drifts are less annoying than an unexpected step change produced by recalibration.

7. My computer brethren frequently lose scope-probe ground clips—the clips get in their way and sometimes short a power supply. I gave up and bought a pile of the clips that I keep in my bench.



8. Sad but true, sometimes adding a scope probe to a malfunctioning circuit makes the circuit work. The probe adds enough capacitance to kill a glitch or stop a race. On floating CMOS, the dc impedance of the scope can be low enough to pull the signal down to a valid level.

9. At one place I worked, I was called to the factory to make my "no-good" circuit work. The complaint was that the dc offset of an op amp was drifting. When I got there, I found the technician had a good DVM connected to the op amp through a piece of coaxial cable to keep out noise. Of course, the cable's capacitance was making the op amp oscillate. You can't measure dc parameters when the op amp is oscillating. Sometimes I find a scope connected this way because the tech wanted more gain or could not find a 10× probe.

10. Probes work into a certain, specified scope-input capacitance. You can't always take a probe that came with one scope and use it at high frequencies on another scope.

11. A simple test technique is waving your hand over a circuit to feel for the hot spot. If something has gone into latch-up but is not smoking, you can frequently find it this way.

12. Edmund Scientific (Barrington, NJ) sells thermally sensitive liquid-crystal sheets, which you can lay over a circuit to find moderate hot spots. This material works well when you have a known-good pc board to compare with the circuit under test.

13. Drafting departments sometimes erroneously think that they own the schematic and that its only purpose is to serve as a wiring diagram for the pc-board layout. Long after pc-board layout, the production-test, sustaining-engineering, and service departments will still need the schematic. Drafting tends to lose notes that I place on the schematic, such as filter poles and zeros, temperature coefficients, normal ac and dc voltages, waveforms, and thermal information. I save myself a lot of calls by putting this information in front of the techs from the beginning.

14. You can make an extremely low-distortion (and slightly microphonic) sine-wave oscillator from a light bulb and an op amp. I got the circuit from Linear Technology's (Milpitas, CA) AN 5 application note. I built a 3-frequency (400-, 1000-, and 2800-Hz) oscillator in a small metal Bud box. It had a THD lower than −80 dB.

15. If a circuit's dc values change when you breath on it, you may have dirty circuit boards.

16. When testing high-gain, low-signal-level circuits, repeat the measurements with the lights off. You may be surprised to learn that many components are photosensitive and have infrared transparent bodies. One of my colleagues had a photosensitive metal-can op amp that leaked light in around the leads.

17. Protection diodes can rectify high-frequency noise and oscillations.

18. Micro Technical Industries (Laguna Hills, CA) makes a handy thermal probe with which you can individually heat components. The probe has tips to fit various components, such as small and large resistors, metal-can op amps, and DIPs of various sizes.

19. Some sample-and-hold circuits are sensitive to slew rates on the digital inputs.

20. Even Schmitt triggers can exhibit metastability.

21. As paraphrased from an Analog Devices (Norwood, MA) application note, "You may be able to trust your mother, but you should never trust your ground."

22. Wrapped-wire circuits work pretty well if you can distribute power and ground properly. I use large-diameter bus wire in a rectangular grid for high-frequency logic if I don't have a wrapped-wire board with internal power and ground distribution.

23. Sometimes powering your test circuit with batteries breaks ground loops and eliminates power-line noise.

24. A handy thing to have is a 60-Hz, passive, twin-T notch filter in a small Pomona box with dual banana plugs for input and output.

25. Another handy thing to have is a 20-dB high-impedance amplifier in another Pomona box. The cir-

cuit in **Fig 1** works at audio frequencies.

26. The CMRR of an op amp is not a constant function of the common-mode voltage. This inconsistency often dominates nonlinearity in noninverting circuits.

27. Getting some engineers to hold design reviews is hard. By law, our drafting department will not start a pc-board design until the designer hosts a review. The drafting supervisor can easily enforce this policy because he does not report to the first-level engineering managers. The moral indignation of the designer's peers informs the quality of the review.

28. Those partial, but detailed schematics National Semiconductor sometimes places on data sheets provide valuable insight into how a part may be acting in unusual circumstances. Please encourage National to continue the practice.

Roy McCammon
3M/Dynatel
Austin, TX

Hello to Mr McCammon:

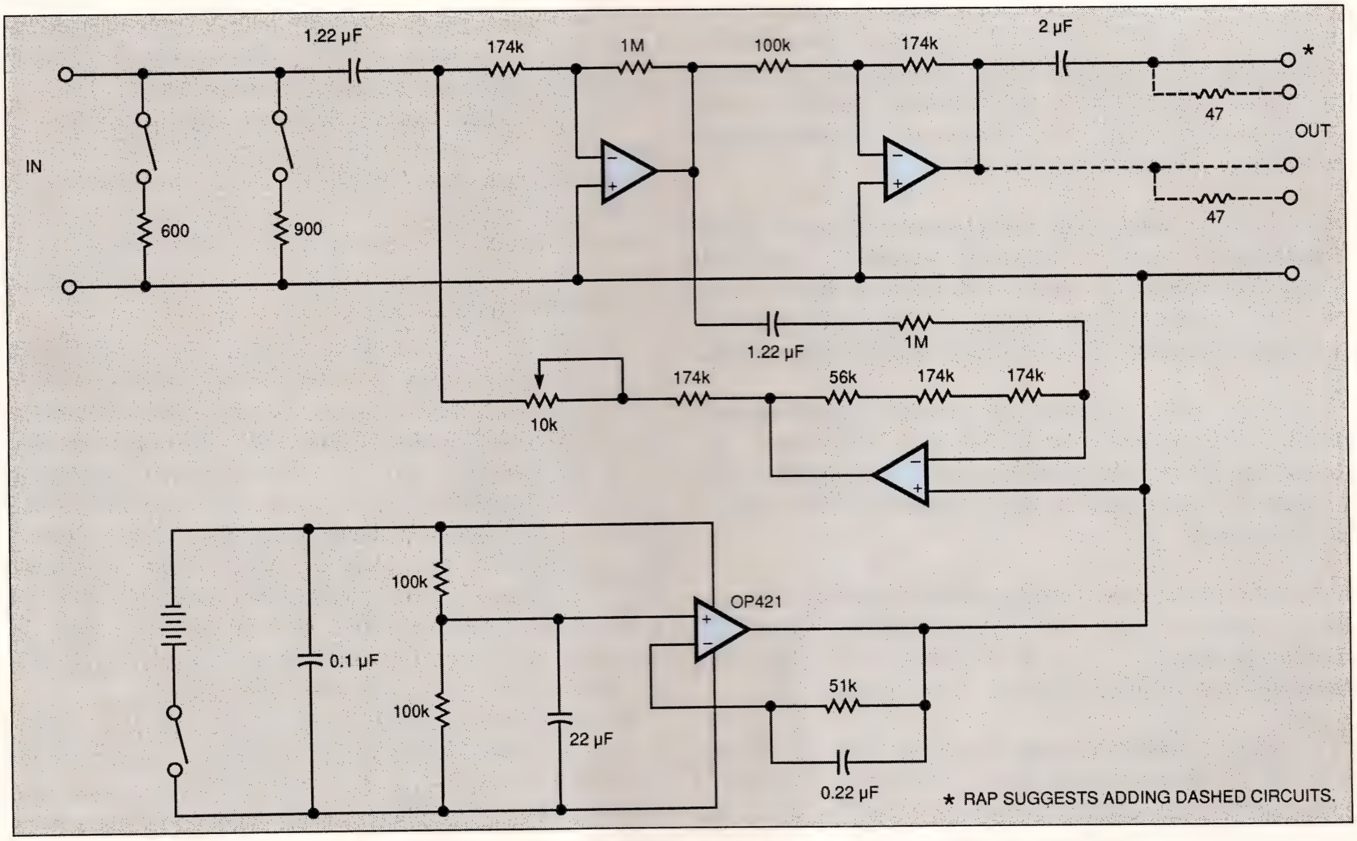
Well, I thank you for your comments, many of which are excellent. I will comment on some of them individually, but, as a collection, they are the best new ideas that anybody has given me.

1. Noise from a video terminal? I have not seen that problem, but such noise may be a serious problem in some cases. I don't have a *digital* computer near my workbench, but other people may. As I mentioned in Part 2 of my series, if you bring an AM radio near a computer or keyboard, the radio will detect various amounts of graunchy RF noises.

2. I, too, recommend RF bypassing. But you point out that bypassing should be *against* ambient RF. I rarely think of bypassing in those terms, but you are right.

6. I agree that spiriting away equipment for calibration is a serious issue. In our group, we used to have equipment disappear for calibration just when we needed the equipment desperately. We finally resolved the problem by requiring that engineers put their equipment on a calibration shelf when it was due to be calibrated. If they don't put it there, the calibration guys won't steal it.

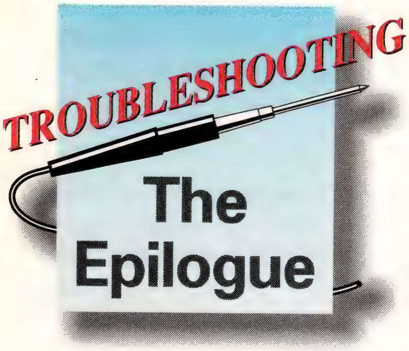
7. Scope probe parts and ground leads do tend to disappear. We have a budget for those items every year, so we avoid running out.



* RAP SUGGESTS ADDING DASHED CIRCUITS.

*Fig 1—**This 20-dB high-impedance amplifier** works at audio frequencies and is a handy troubleshooting aid.*

9. You are right that adding a chunk of coaxial hose on an op-amp's output can sure make it unhappy, more often than doing so makes it happy. You are right to complain that foolish people pull such stunts. "Show me where it says I can't do it," they protest. *(Ed Note: The Sufis have a saying, "There's no point in putting up signs in the desert saying, 'Thou shalt not eat rocks.' ")*



10. Good statement about probe compatibility. Sometimes you turn the adjustment all the way to the end, and the probe still won't neutralize out.

11. Good point. I often check my soldering iron by running the tip past my nose—about one inch away—to see if it's good and hot. *(Ed Note: Humans have infrared receptors in their lips. If you close your eyes and slowly raise the back of your hand past your lips, you should be able to sense the presence of your hand. Use the back of your hand because the callouses on the palm of your hand block heat radiation.)*

13. You point out that " . . . drafting departments tend to lose notes." Well, where *I* work, drafting departments do a task, and if that includes adding notes, then they add whatever the engineer requires. Actually, I usually do my own draftpersoning. Some people gripe, but the information is all there.

14. I don't usually get too enthusiastic about using incandescent lamps for amplitude control. It's true that most oscillators don't have distortion as low as −80 dB, but you can put the output of a mediocre oscillator through a filter and get distortion lower than −80 dB.

17. "Protection diodes can rectify high-frequency noise." I have never seen this one. Boy, Roy, you must live in a *nasty* neighborhood for ambient RF noises. You can probably run a transistor radio without any batteries.

18. I forgot to even mention thermal probes. We use such probes more for characterizing than for troubleshooting. Often, a soldering iron does the troubleshooting job faster but more crudely.

19. The LF198 data sheet mentions that you should not let the Sample input move too slowly. Are there other S/H circuits that are touchy? Ones that do not mention this fact in their data sheets?

22. I rarely work with wrapped-wire stuff, but I bet a lot of people get fooled by bad daisy-chaining of power-supply runs and lousy power-supply bypassing—whether for linear or digital ICs.

23. I rarely find batteries necessary, but, in extreme cases, they are useful.

24. I rarely find notching out 60- or 120-Hz interference necessary. I usually subtract the 60-Hz noises visually from a scope trace.

27. Design reviews are a good idea. But even if the circuit design is perfect, I find the layout to be pretty critical. So a beer check by all your buddies is awfully important, too.

RAP

Reader's letter causes change of heart

Dear Bob:

As a practicing technician for many years, I want to comment on one or two things I read in your series and perhaps pass on an experience or two.

On pg 130 of the August 17, 1989, article, you mention the possibly harmful side effects of drawing base current out of a transistor. Most (if not all) of the switched-mode power supplies I have come across appear to do just that—to switch the transistor off more quickly by removing carriers from the base.

This technique appears to work well in practice. I have used the technique in many of the inverters I have designed, and (on the face of it, at least) there doesn't appear to be any component deterioration over time. I usually use some form of reverse-voltage limiting to ensure that the base-collector junction doesn't undergo zener breakdown.

On pg 132 of the same article, I read something about plugging MOS ICs into "live" sockets—I presume you mean "powered up." If so, I could not personally recommend doing so because I have seen people cook devices that way. You also mention something about not wearing ground straps when handling MOS ICs. I certainly can't agree with this advice, either. My experience, and that of others, has been that MTBFs plummet if you don't handle MOS ICs with kid gloves. The problem is that the device rarely fails on the spot, but having possibly been overstressed, will do so at a time and place of its own choosing.

Turning to the article in the September 28, 1989, edition of EDN, I feel bound to present a caution regarding tantalum capacitors. First, they are even less tolerant of reverse polarity than electrolytic capacitors are. Reverse polarity can arise when, say, coupling op amps with tantalum capacitors. Second, I have replaced more tantalum capacitors than I can remember because they short-circuited for no good reason.

The worst place for a bad tantalum capacitor is on a computer mother board, which is just where I found the last one I replaced. The job started out as a short that was shutting down the power supply. Ascertaining which rail the problem was on was easy enough. I decided that because of the number of components on the bus, I would have to try something less radical than temporarily isolating a section of the rail. I tackled the problem by feeding a 10-kHz sine wave at about 1V rms through a 1-kΩ resistor and monitoring the traces with a current probe. I found the offending component in less than a minute. I may have been lucky, but, on the other hand, my test signal wouldn't cause the ICs to draw any significant current and was of a low-enough frequency not to cause enormous current in the good decoupling capacitors.

In the same article, you said that floating TTL inputs is reasonably OK. In some situations, particularly noisy ones, I would have to disagree. I have seen nasty problems where this practice causes random glitches. The circuit in **Fig 2** is an absolute nightmare. Yet this practice is common on IBM PC clones from Asian manufacturers in, of all things, the glue logic of 80386 mother boards, where high-speed clocks are the norm.

Michael Watts
Wellington Polytechnic
Wellington, New Zealand

Dear Mr Watts:

Thank you for your comments. You question the practice of pulling current out of a transistor's base circuit. If you were to actually pull current out of the base and forward-bias the transistor's intrinsic base-emitter zener, you could cause damage. If, instead, the circuit prevents zener breakdown and its clamps prevent excessive reverse V_{BE}, then everything is fine. I probably wasn't clear enough about those points. Note that many discrete transistors are not as fragile—are not going to be damaged or degraded by zener breakdown—as monolithic transistors are. (I'm not sure why.)

Also, you recommend against plugging CMOS components into live (powered-up) circuits and working without a ground strap. You say you have seen such procedures directly cause unreliability and failures. OK, you have and other people have, but I haven't. Perhaps RAM chips are more fragile than 74Cxx chips. So, I must retract my cavalier and flippant remarks: In general, you should use ground straps and not plug ICs into live circuits unless you are *sure* you know what you're doing and are prepared to accept IC failures.

However, when troubleshooting, sometimes you may have to resort to these measures. You should then be aware that they may not necessarily cause harm. But I, and the readers, should be aware that sometimes they may cause harm, so don't hack around if you don't have to.

As for tantalum capacitors, I've seen very few fail with no provocation. I've used a lot of cheap tantalum capacitors, and they must have been more reliable than I deserved. To ensure that they survive reversal, I suggest the arrangement in **Fig 3**.

Using a current probe to find short circuits is a viable technique, but I don't understand how you can clip a current probe around a board trace. I find that my dc microvolt detector, which appeared in Part 2 of the series, will let you track down such dc shorts. If I had to troubleshoot a lot of boards, I'm sure one of your audio-output, milliwatt detectors would be terribly useful.

Although I've never seen a problem with floating TTL gates, you are correct to caution against circuits like the one in **Fig 2**.

RAP

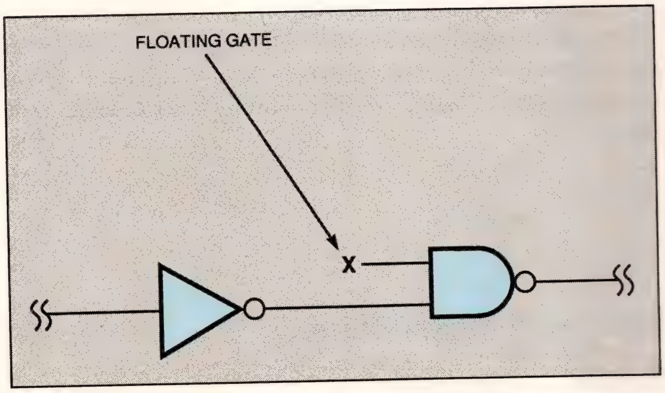


***Fig 2—Letting TTL gates float** is a potentially dangerous practice.*

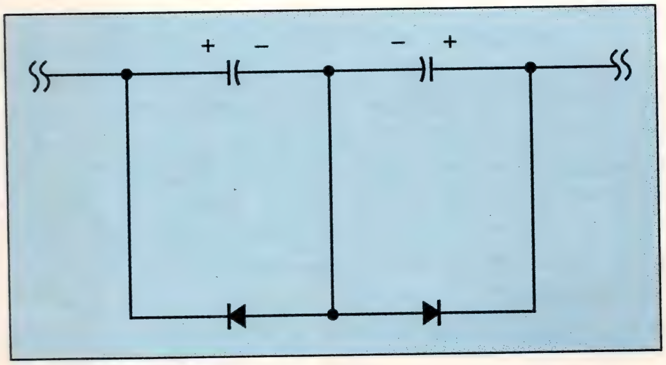


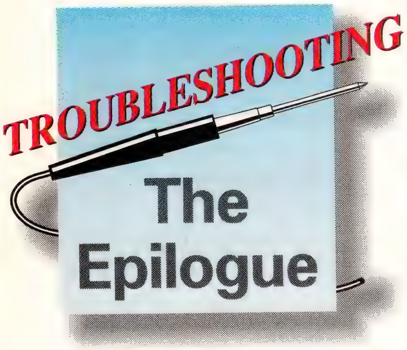
***Fig 3—This scheme will make your tantalum capacitors** immune to damage from reversal.*

Old hand passes on secret TTL lore

Dear Bob:

As an old hand with 30 years in the business, I have run into some anomalies you did not mention.

1. LS logic is totally unforgiving of negative undershoots at its inputs. The worst chips I have seen are 74LS86s, which hang up for microseconds, totally confusing other circuitry. The second worst is the 74LS75, which can go into either logic state after a negative undershoot but will recover upon the next clock pulse.



2. I have seen circuits with a 7470, -73, -76, -107, -109, -110, or -111 that "remember" highs on the Preset and Reset lines and toggle in spite of a low-high condition at clock time. This anomaly happens if the clock is left high and is not pulsed.

J Koontz
Chief Engineer
Computer Automation
Irvine, CA

••••••••••••••••••••

TV chassis tells a tale for all to hear

Dear Bob:

If an engineer wants to see how to properly control EMI at its source, he or she should look at the chassis of any TV and tuner. Chances are, any radiation from internally generated 15-kHz to 950-MHz signals meets FCC Part 15 rules. Obviously, most TV receivers do not depend on their plastic cabinets to contain spurious radiation.

For some time now I have been working with labs that attempt to certify radiating equipment that was not designed using basic radiation-containment methods. These methods date back to the time of tube circuits and include using specialized components such as feedthrough capacitors, ferrite beads, and toroidal coils. These methods also include using very light-gauge, low-cost, tin-plated steel cans to enclose radiating components. Soldering the tabs of these 5-sided cans to the pc board forms a complete 6-sided enclosure around the radiating component. Note that TV receivers' pc boards have considerable ground-plane area.

If you do not design out EMI, someone will have to design in some Band-Aids to fix your bad design.

Here are some points to consider:

1. Incorporate as much ground plane as possible on one side of each pc board that contains digital or analog signals above audio frequencies. Be sure this ground plane has a low-inductance path to the main chassis—even if this path goes through an edge connector.

2. Incorporate a T or L RC filter on all input and output lines. The resistor should always be on the side leading away from the hot circuit. It should be the largest value possible, as great as 1 kΩ. This resistor will damp, or "de-Q," any resonant circuit that the interconnect lines form as well as filter the noise. You must choose the resistor and capacitor carefully so as not to adversely affect the desired signal on the line. The capacitor should be a ceramic disk with a value between 10 pF and 0.01 μF, depending on the signal source. Probe each filtered line to confirm that only required signals are present.

3. Probe each pc board to locate the areas of maximum radiation. Experiment with metal-foil tape to determine where a metal shield will be most effective. Install a temporary shield soldered to the ground plane to verify effectiveness.

4. You should examine purchased items such as disks and power supplies for I/O-line filters and radiation containment.

5. A commercially available filter or a suitable substitute should filter your circuit's input ac power line. Probe the ac-power input to check that any conducted interference is at least 20 dB below requirements.

6. Monitor your circuit's I/O lines during normal operation and track down any unexpected signals to their source. Again, any conducted interference should be at least 20 dB below requirements.

7. No matter how you measure the near-field radiation from your design, such radiation should be at least 20 dB below the 3-meter radiation limit. To make these measurements, you'll need a shielded, screened test room.

Thomas L Fischer
Pacific West Electronics
Costa Mesa, CA

••••••••••••••••••••

Protection diodes generate heat

Dear Bob:

You recommend using "antireversal" diodes across a power supply's input to protect circuitry against reversal of the power supply's leads (See **Fig 4** on pg 126). However, if a power supply does get hooked up backwards, high currents will flow through the diodes, which might degrade or ruin them. Remember, the diodes *are* a part of the circuitry, too. Instead, I recommend connecting the diodes in series with the input pins (**Fig 4b**).

Now, the board has protection but with virtually no diode current.

Marvin Smith
Harbor City, CA

Dear Mr Smith:

You are correct in some cases, and I guess I was delinquent in not mentioning them. For example, if you have a battery, putting the diode in series with the correct path may be appropriate. Then, if reversal happens, the battery won't be crowbarred and you will avoid damage to the battery and its environs. However, if you have a 5V bus, a diode in series with the supply would both waste a large fraction of the total voltage and possibly spoil the supply's regulation.

Even with a 15V supply, where the wasted power might be acceptable, the bounce and poor regulation of the supply might hurt the accuracy of the circuits that the supply powers. The diode's impedance may cause poor regulation. So, in cases where a regulator drives the power buses, the shunt antireversal diodes are a good idea. The solution presumes, of course, that the regulators are short-circuit proof.

The worst part of your circuit, Mr Smith, comes to light when one of the power-supply wires falls off or becomes disconnected. Then, the −14V bus could get pulled to 5 or 10V, depending on what loads are between the 14 and −14V buses. Many linear circuits can get very unhappy if fate pulls their negative-supply pin above ground. Even if the ICs didn't complain, the electrolytic power-supply bypass capacitors would be reverse-biased, a potentially destructive situation.

So, Mr Smith, would you agree that adding a couple additional antireversal rectifiers to your circuit would probably be a good idea?

Now, in what cases should designers *not* incorporate your series diodes without adding parallel antireversal diodes? The answer is low-voltage, high-current, or well-regulated applications.

Of course, you are correct that the rectifiers must be able to carry the short-circuit current of the regulator. Fortunately, 1N4002s are very inexpensive these days. Further, 1N5400s, which carry 3A, are only 19¢ each.

Best regards, and thank you for your comments. You are wise to "question authority."

RAP

Czar of Floobydust

PS: Whoops! Let's say you put diodes in series with your path, with a couple batteries for supplies. Now, if you short out the 14V buses, how can you be sure that your rectifier won't get ruined? Maybe you need to put a fuse in series with each diode? Maybe I ought to put a fuse in series with my supply buses? It just goes to show, things are not simple any more!

So Bob, what do you think about solderless breadboards?

Here's a chunk of late-breaking floobydust—the topic is those solderless breadboards, which consist of a number of metal strips and solderless connectors hidden underneath a plastic panel with lots of holes in it. Schools often use them to introduce students to the joys of breadboarding because you can easily connect things by just stuffing wires and components into the holes. The problems begin with capacitance. The breadboards usually have 2, 3, or 5 pF between adjacent strips. On a good day, only a wise engineer could plan a layout that all the capacitors, sprinkled throughout the circuit, wouldn't ruin.

The next serious problem with solderless breadboards is the long leads, which make adding effective power-supply bypass capacitors close to a chip difficult.

Next, I suspect that some of these panels, although they are not inexpensive, use cheap plastics such as nylon. On a warm, humid day, cheap plastics do not offer high insulation resistance. Nobody wants to talk about what kind of plastic the breadboards are made of.

Finally, Mr Scott Bowman of Dublin, CA, points out that after you insert enough wires into any given hole, the solderless connector will scrape sufficient solder off the wire so that the scraps of solder will pile up and start to intermittently short out to an adjacent strip. Further, the adhesive that holds on the back panel tends to hold the solder scraps in place, so you can't clean the scraps out with a solvent or a blast of air.

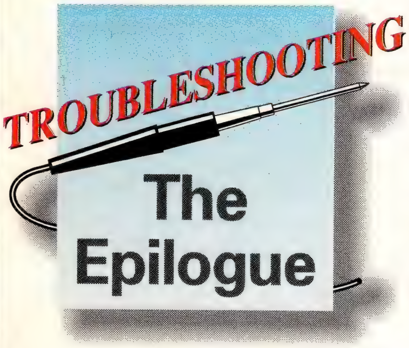
I didn't even think about these solderless breadboards when I wrote my series because I see them so rarely at work. They just have too many disadvantages to be good for any serious work. So, if you insist on using these slabs of trouble, you can't say I didn't warn you.

RAP

The discrete charm of Popsicle sticks

Dear Bob:

To make component probes for debugging circuits, I glue capacitors or resistors on the ends of Popsicle sticks with epoxy. I keep the components' leads short—about ¼ in.—and cut at an angle to form precise contact points. Thus, you isolate your finger and body capacitance from the actual value of the component.



The Popsicle stick has a couple of advantages over simply grasping the component with your fingers or mounting it in a length of heat-shrink tubing. First, the Popsicle stick is more rigid than heat-shrink tubing. Second, the added length of the Popsicle stick often proves handy. I've got a whole box of capacitors and resistors mounted this way, which makes for a very efficient and portable trimming kit.

John Ardizzoni
M/A-COM
Lowell, MA

Taking care of heat buildup

Dear Bob:

I use Tempilaq temperature-indicating paint from Tempil (South Plainfield, NJ) to monitor the temperature of power devices in metal cans and plastic packages, such as TO-220 devices. I use the paint both in development and in units shipped to the field.

The substance comes in various temperature grades. I anoint the top of each device with a range of paints. When and if a device heats up, each temperature-grade paint melts and fuses at a specific temperature, permanently altering the substance's appearance.

I also use the paint to ascertain the relative effectiveness of various thermally "conducting," insulating washers. These washers isolate a power device from its heat sink. I measure the time for the paste to change state after applying power to a device.

I discovered that silicon-based, elastomeric washers didn't work at all with TO-220 cases. The mounting screw of these cases is off center. One end of the case is tight, and the other is loose, which causes poor heat flow. I don't understand why these washers are even manufactured. Didn't the makers try one out before deciding to offer them?

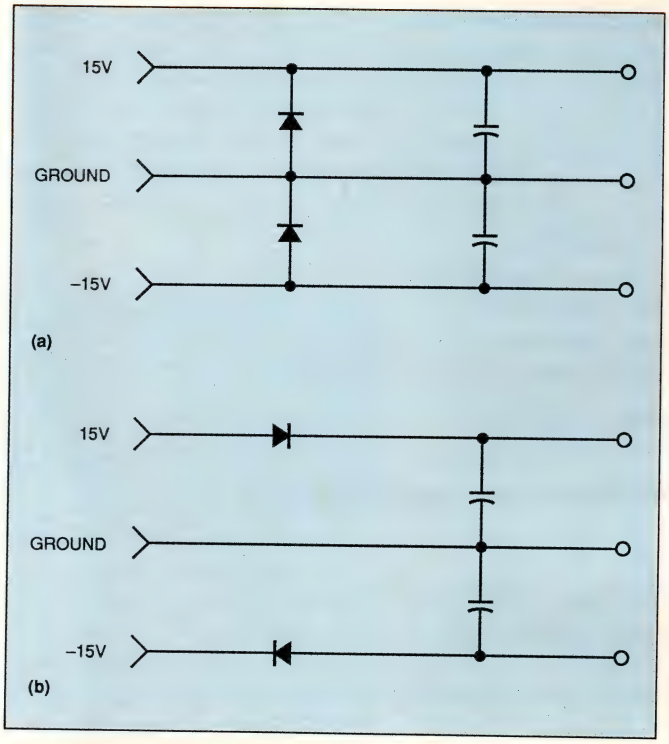


Fig 4—Depending on your application, you may want to connect antireversal diodes across (a) or in series (b) with a power supply's input pins.

Washers aren't the only problem. One sample TO-220 device got hot so quickly that I performed a post mortem on it. I opened the package and pried the chip loose and observed that only about 15% of the die had been bonded to the substrate. Since that experience, I have steered clear of that particular manufacturer.

Bill Sturgeon
Sturgeon Engineering Co
Petrollia, CA

Dear Mr Sturgeon:

Thanks for your tip. Most of the guys in our lab don't use Tempilaq, but it's a good tip. We use thermocouples on the can or diodes in the chip.

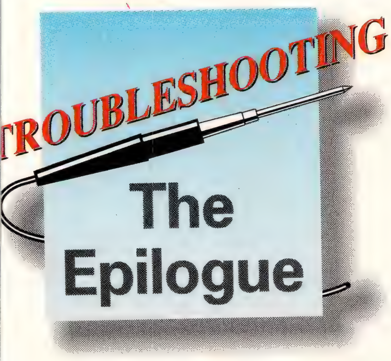
RAP

Another reason to distrust computers

Dear Bob:

You're right. Most people, even technical people who should know better, tend to treat any numeric display or computer readout as if it were engraved in stone, ignoring whatever imperfect mechanism generated digits. They're even in awe of numbers scratched in Jello.

Back in the sixties, there was a story circulating about the Apprentice Engineer who had been experimenting with the plant's new analog computer. He ran up to the Chief Engineer waving a sheaf of printouts. "Look," he said excitedly, "I've come up with a simulation of our power-plant heating and air-conditioning system that will double the plant's efficiency!" The Chief Engineer studied the printout for a few moments. "Yes," he said, "but look here." And he pointed to the flow diagram, "This 17°F water is going to be awfully hard on the pumps."



Your frustration with the menu burden of these wonderful new instruments is right on target. One thing that I detest intensely and that seems to occur with increasing frequency is staring blankly at a screen or cursor, knowing full well that the reason it obstinately refuses to do your bidding is almost certainly a consequence of your imperfect understanding of its menus and possibly also of your failure to read the manual all the way through—which you'll do the next time you have a spare week. Keep up the good work.

Reginald W Neale
Connoisseur of Solder Globs
Rochester, NY

……

Diode-connected confusion clears

Dear Bob:

I'm really confused by your apology on page 34 of the November 23, 1989, issue of EDN. I understand about diode-connected transistors; we use them often. However, we connect the base to the emitter and thereby use the base-collector junction. The breakdown voltage of such a connection is typically about the same as the transistor's maximum V_{CE} rating. If we use your method, the breakdown rating will be only 5 to 7V typ, according to data sheets. I usually want more.

John Paul Hoffman
Caterpillar Inc
Peoria, IL

So Bob, what do you think about spreadsheets?

Normally, I hate, despise, and detest using spreadsheets for linear-circuit design. They give you an answer, but they don't give you much feel for what is important.

Dear Mr Hoffman:

You're right, the collector-emitter junction can handle more current than the base-emitter junction, but it's also slower.

RAP

……

Hobbyist learns about life

Dear Bob:

A few years ago, when I first moved into a new house and hooked up my stereo, the left channel decided to fry the output transistors. The power amp had heavy feedback and was a standard design running class A or AB. It had a "tweak" for nulling out standing current in the output stage. I found that as I monitored and increased the standing current in the left channel, the left stage would run away at a standing-current value, which the right channel could handle with no problem.

Now I was confused. I had two identical circuits, one of which was fine and the other of which wouldn't tweak up to spec. I noticed that if I was probing certain nodes in the left channel with my scope, the left channel wouldn't run away. The scope didn't show anything abnormal, but I suspected that something was causing the circuit to oscillate.

Now—one very important detail: My new house was two blocks from the top of a hill covered with an antenna farm—including an AM broadcast station at 970 kHz. The bandwidth of my stereo's power amp was well over 1 MHz. I discovered that if I hung a 0.1-μF capacitor from both sides of the power-line entrance to chassis ground, everything was fine. EMI was coming down the power line causing the circuit to break into destructive oscillation. I couldn't see the oscillation on the scope because the scope's ground lead shunted the EMI to power-line ground.

I learned that

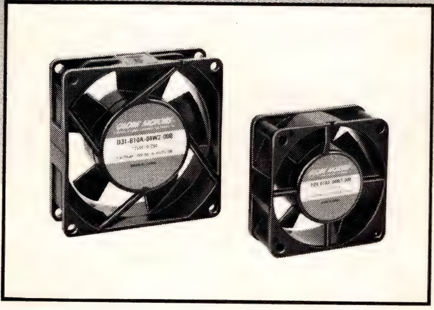
1. Identical circuits aren't necessarily.

2. Marginal designs that work on the bench may fail when put into service.

3. Look for clues anywhere.

Thanks again for some great articles!

QUALITY FANS, PRICED RIGHT!



With its complete line of AC and brushless DC Commercial Cooling Fans, Globe Motors stocks the right fan for your cooling application needs!

- 115 and 230 VAC models to 215 CFM
- 12 and 24 VDC models; 8 to 110 CFM
- 60mm to 150mm x 172mm sizes
- Solid state brushless design; precision ball bearings
- 50,000 hr. min. life; quick delivery

GLOBE MOTORS
A Division of Labinal Components and Systems, Inc.
For more information, contact Globe Motors, 2275 Stanley Ave., Dayton, Ohio 45404.
513-228-3171

CIRCLE NO. 9

Galileo had to invent the most technologically advanced test equipment of his time. You can rent.

Galileo had to devise the telescopes that proved the Earth revolves around the Sun. Today, finding the best test equipment is simple. Rent from Leasametric. Meticulously inspected, tested and calibrated. Flexible, competitive terms. Overnight delivery.

U.S.: 800-553-2255 • Canada: 800-268-6923

Leasametric, Inc.
Electronic Equipment-Renting, Leasing, Sales and Service
A member of The Marmon Group of companies

CIRCLE NO. 11

Steve Coffman
TSSI
Beaverton, OR

Dear Mr Coffman:

I think you forgot a fourth point:

4. If some bandwidth is good and some more bandwidth is better, then lots and lots of bandwidth is not best—it may just be a disaster! Giving a power amplifier lots and lots of bandwidth is one good way to buy trouble. But I find it interesting that the 970-kHz EMI came in on the power line and not on the speaker cables.

RAP

••••••••••••••••••••

The troubleshooting series at a glance

Part 1—"Troubleshooting is more effective with the right philosophy," *EDN*, January 5, 1989, pg 147.

Part 2—"The right equipment is essential for effective troubleshooting," *EDN*, January 19, 1989, pg 166.

Part 3—"Troubleshooting gets down to the component level," *EDN*, February 2, 1989, pg 175.

Part 4—"A knowledge of capacitor subtleties helps solve capacitor-based troubles," *EDN*, February 16, 1989, pg 127.

Part 5—"Follow simple rules to prevent material and assembly problems" *EDN*, March 2, 1989, pg 159.

Part 6—"Active-component problems yield to painstaking probing," *EDN*, August 3, 1989, pg 127.

Part 7—"Rely on semiconductor basics to identify transistor problems," *EDN*, August 17, 1989, pg 129.

Part 8—"Keep a broad outlook when troubleshooting op-amp circuits," *EDN*, September 1, 1989, pg 131.

Part 9—"Troubleshooting techniques quash spurious oscillations," *EDN*, September 14, 1989, pg 151.

Part 10—"The analog/digital boundary needn't be a never-never land," *EDN*, September 28, 1989, pg 145.

Part 11—"Preside over power components with design expertise," *EDN*, October 12, 1989, pg 177.

Part 12—"Troubleshooting series comes to a close," *EDN*, October 26, 1989, pg 171.

Bob Pease illustration by Bruce Gilfoy

Article Interest Quotient (Circle One)
High 488 Medium 489 Low 490

We've drastically reduced the time it takes to produce a baby.

If you've been laboring under the assumption that Video RAMs have gotten about as fast as possible, Toshiba would like to introduce you to their new 1 Megabit creations.

With faster read/write features, they have a bright future in all kinds of applications.

Ultrasound monitors, for instance.

Or personal computers. Magnetic Resonance Imaging equipment. Video games. If it can benefit from getting an image out of the gate and onto the screen faster, it can use a healthy dose of Toshiba 1 Megabit high density VRAM.

For the best delivery of these babies, just call Toshiba's only national distributor. Marshall Industries. As Toshiba's number one distributor nationwide, we always have plenty of product on hand, so you can start designing whole new families right away.

In fact, the whole concept is, well, pregnant with possibilities.

Marshall

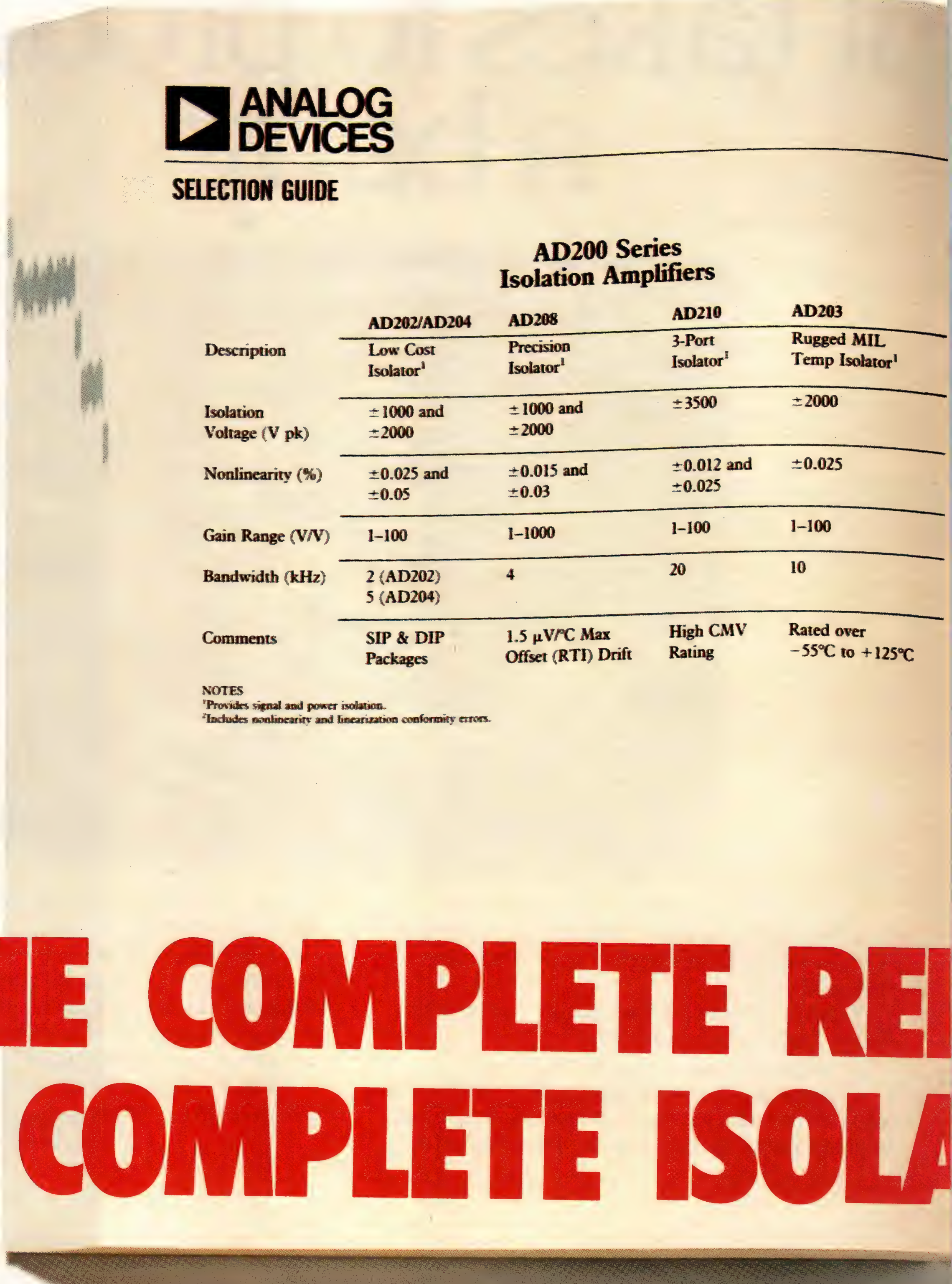
(*Authorized Locations)
AL Huntsville (205) 881-9235*
AZ Phoenix (602) 496-0290*
Tucson (602) 790-5687*
CA Irvine (714) 458-5301*
Los Angeles (818) 407-4100*
Sacramento (916) 635-9700*
San Diego (619) 578-9600*
San Francisco (408) 942-4600*
CO Denver (303) 451-8383*
CT Connecticut (203) 265-3822*
FL Ft. Lauderdale (305) 977-4880*
Orlando (407) 767-8585*
Tampa (813) 573-1399*
GA Atlanta (404) 923-5750*
IL Chicago (312) 490-0155*
IN Indianapolis (317) 297-0483*
KS Kansas City (913) 492-3121*
MA Boston (508) 658-0810*
MD Maryland (301) 622-1118*
MI Michigan (313) 525-5850*
MN Minneapolis (612) 559-2211*
MO St. Louis (314) 291-4650*
NC Raleigh (919) 878-9882*
NJ N. New Jersey (201) 882-0320*
Philadelphia (609) 234-9100*
NY Binghamton (607) 798-1611*
Long Island (516) 273-2424*
Rochester (716) 235-7620*
OH Cleveland (216) 248-1788*
Dayton (513) 898-4480*
OR Portland (503) 644-5050*
PA Philadelphia (609) 234-9100*
Pittsburgh (412) 788-0441*
TX Austin (512) 837-1991*
Dallas (214) 233-5200*
El Paso (915) 593-0706*
Houston (713) 895-9200*
San Antonio (512) 734-5100*
UT Salt Lake City (801) 485-1551*
WA Seattle (206) 486-5747*
WI Wisconsin (414) 797-8400*
In Canada: G.S. Marshall Co.
Montreal (514) 694-8142*
Ottawa (514) 694-8142*
Toronto (416) 458-8046*

CIRCLE NO. 75

Now your "make vs. buy" dilemma for protecting your system from high common mode voltages, transients or ground loop currents is over. Because Analog Devices has a wide range of low cost, high performance, compact isolation products that improve your time-to-market while they reduce your design costs.

Our AD200 Series of isolation amplifiers and 1B Series of isolated signal conditioners provide up to 3500 V CMV isolation to guard against damage from transients and fault voltages. They offer both signal and power isolation, making them functionally complete and eliminating the need for external dc/dc converters. And they're component-sized to save valuable board space.

Actual size not shown.



ANALOG DEVICES

SELECTION GUIDE

AD200 Series Isolation Amplifiers

	AD202/AD204	AD208	AD210	AD203
Description	Low Cost Isolator[1]	Precision Isolator[1]	3-Port Isolator[2]	Rugged MIL Temp Isolator[1]
Isolation Voltage (V pk)	±1000 and ±2000	±1000 and ±2000	±3500	±2000
Nonlinearity (%)	±0.025 and ±0.05	±0.015 and ±0.03	±0.012 and ±0.025	±0.025
Gain Range (V/V)	1–100	1–1000	1–100	1–100
Bandwidth (kHz)	2 (AD202) 5 (AD204)	4	20	10
Comments	SIP & DIP Packages	1.5 μV/°C Max Offset (RTI) Drift	High CMV Rating	Rated over −55°C to +125°C

NOTES

[1] Provides signal and power isolation.

[2] Includes nonlinearity and linearization conformity errors.

THE COMPLETE RE

COMPLETE ISOL

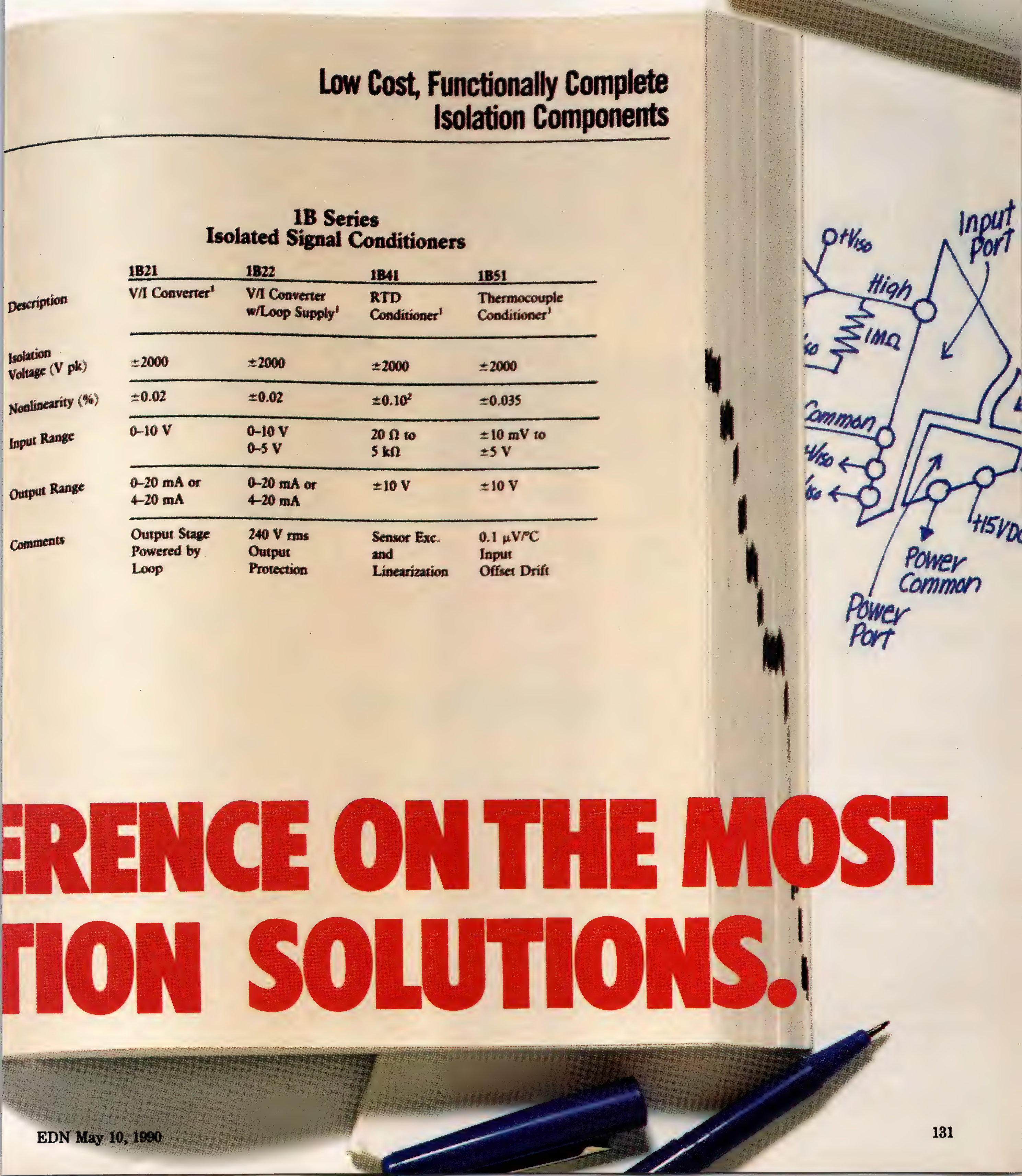
They'll also boost your overall performance levels because both provide superb common mode noise rejection and low drift for maximum accuracy. Additionally, the 1B Series includes CJC interface for thermocouples, sensor excitation and linearization for RTDs, or isolated power for process control loops.

For more reference material on the AD200 Series and 1B Series, contact your nearest Analog Devices sales office.

ANALOG DEVICES

CIRCLE NO. 76

Analog Devices, Inc., One Technology Way, P.O. Box 9106, Norwood, MA 02062-9106. Offices and applications support available worldwide. Austria: (222) 885504-0; Belgium: (3) 237 1672; Denmark: (42) 845800; France: (1) 4666-25-25; Holland: (1620) 81500; Israel: (52) 911415; Italy: (2) 6140977, (2) 6143484, (2) 6143459; Japan: (3) 263-6826; Korea: (2) 5543301; Sweden: (8) 282740; Switzerland: (22) 731 57 60; United Kingdom: (932) 232222; West Germany: (89) 570050; U.S. and all others: (617) 329-4700.



Low Cost, Functionally Complete Isolation Components

1B Series Isolated Signal Conditioners

	1B21	1B22	1B41	1B51
Description	V/I Converter[1]	V/I Converter w/Loop Supply[1]	RTD Conditioner[1]	Thermocouple Conditioner[1]
Isolation Voltage (V pk)	±2000	±2000	±2000	±2000
Nonlinearity (%)	±0.02	±0.02	±0.10[2]	±0.035
Input Range	0–10 V	0–10 V 0–5 V	20 Ω to 5 kΩ	±10 mV to ±5 V
Output Range	0–20 mA or 4–20 mA	0–20 mA or 4–20 mA	±10 V	±10 V
Comments	Output Stage Powered by Loop	240 V rms Output Protection	Sensor Exc. and Linearization	0.1 µV/°C Input Offset Drift

FLUKE AND PHILIPS – THE GLOBAL ALLIANCE IN TEST & MEASUREMENT

FLUKE®

PHILIPS

PHILIPS

Power packed DSO choices upto 250 MS/s.

20 MS/s - 60 MHz

100 MS/s - 60 MHz

100 MS/s - 100 MHz

250 MS/s - 60 MHz

250 MS/s - 100 MHz

Now, Philips offers you more power packed choices in mid-frequency digital storage oscilloscopes. With a new range of five models, from entry-level to advanced.

Each one is a breakthrough in performance and ease of operation. And each one is priced to give you unexpected economy.

Operation is simple and intuitive - just like a conventional analog instrument. With full analog functionality for real - time signal display and measurements.

But just select 'digital memory' to get powerful DSO facilities. Letting you capture, compare and analyze both single - shot and repetitive signals.

So check the features and performance of these power packed instruments. And see for yourself why they add up to unbeatable value in digital storage.

- ■ ***PM 3335*** *20 MS/s sampling rate, large 8 K deep memory, 60 MHz analog bandwidth, full cursor measurements, combined GPIB/IEEE - 488 - RS232 - C interface option.*
- ■ ***PM 3350A*** *100 MS/s sampling simultaneously on both channels, 60 MHz analog bandwidth, 4 memory registers, fast - action 'intelligent cursors', Digitally Delayed Timebase, GPIB/IEEE - 488 or RS232 - C interface options.*
- ■ ***PM 3365A*** *100 MS/s sampling simultaneously on both channels, plus repetitive sampling at up to 100 MHz, 100 MHz analog bandwidth, 4 memory registers, extra signal - processing modes, Digitally Delayed Timebase, GPIB/IEEE - 488 or RS232 - C interface options.*
- ■ ***PM 3355*** *Fast 250 MS/s sampling simultaneously on both channels, 60 MHz analog bandwidth, 4 memory registers, fast - action 'intelligent cursors', Digitally Delayed Timebase, GPIB/IEEE - 488 or RS232 - C interface options.*
- ■ ***PM 3375*** *Fast 250 MS/s sampling simultaneously on both channels, plus repetitive sampling at up to 100 MHz, 100 MHz analog bandwidth, 4 memory registers, fast - action 'intelligent cursors', Digitally Delayed Timebase, GPIB/IEEE - 488 or RS232 - C interface options.*

To find out more about the power packed choices in mid-frequency DSOs, just contact your local sales office:
Austria *(0222) 60101-1772,* ***Belgium*** *(02) 5256692/94,* ***Denmark*** *(31) 572222,*
Finland *(0) 5026371,* ***France*** *(1) 49428080,* ***Germany*** *(561) 501466,*
Great Britain *(923) 240511,* ***Ireland*** *(61) 330333,* ***Italy*** *(039) 3635240/8/9,*
Netherlands *(13)390112,* ***Norway*** *(2) 741010,* ***Portugal*** *(1) 683121,*
Spain *(1) 4042200,* ***Sweden*** *(8) 7031000,* ***Switzerland*** *(1) 4882390.*
For countries not listed, write to: Philips I&E, T&M Department,
Building TQ III-1, 5600 MD Eindhoven, The Netherlands.

ADVANCED TECHNOLOGY
MADE TO MEASURE

PHILIPS

PHILIPS

CIRCLE NO. 78

Use Spice to solve problems on high-speed digital boards

As digital clock rates reach 50 MHz and head toward 100 MHz, high-frequency effects such as crosstalk and transmission-line reflections can create serious problems. Microwave simulators can help you diagnose and eliminate potential trouble spots before you commit your design to hardware.

Octavius Pitzalis, Jr and Thomas M Reeder,
EEsof Inc

Until recently, high-frequency effects were of little concern to digital-board designers. Clock speeds below 25 MHz made interline crosstalk and transmission-line reflections insignificant problems compared with figuring out how to fit hundreds of components on the board and then making the board manufacturable. After all, transmission-line problems are the domain of microwave engineers, not digital designers—right?

Wrong. Times and technology are changing. A recent industry forecast predicted that 50% of all digital pc boards will run at clock rates higher than 50 MHz by 1991 (**Ref 1**). A technology report from Intel placed leading-edge microprocessors at 100 MHz by 1995 (**Ref 2**). Moreover, objectionable transmission-line effects begin to appear when the length of adjacent board traces reaches one-tenth of a wavelength (where the wavelength is defined relative to the clock frequency). As a rule of thumb, that works out to be a worst-case length defined by

L = 600 in. ÷ clock frequency (MHz),

or about 6 in. at 100 MHz (**Ref 3**). Consequently, many digital boards now being designed have dimensions

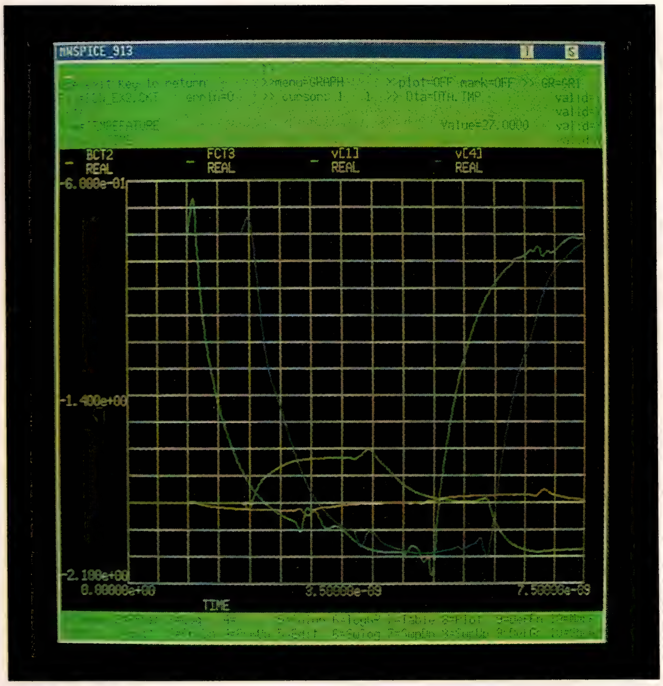


Fig 1—This simulation plot shows interline coupling *between adjacent conductors that are driven and loaded by MECL 10KH logic gates.*

Objectionable transmission-line effects begin to appear when the length of adjacent traces reaches one-tenth of a wavelength (relative to the clock).

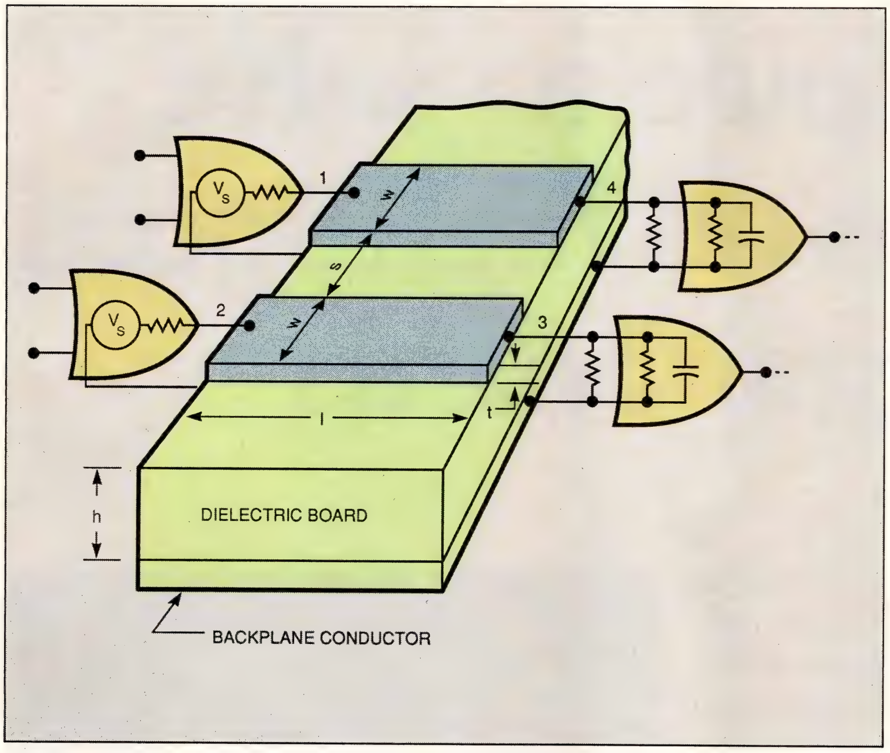


***Fig 2—This schematic view of transmission lines** on a high-speed digital logic board shows how coupling can occur.*

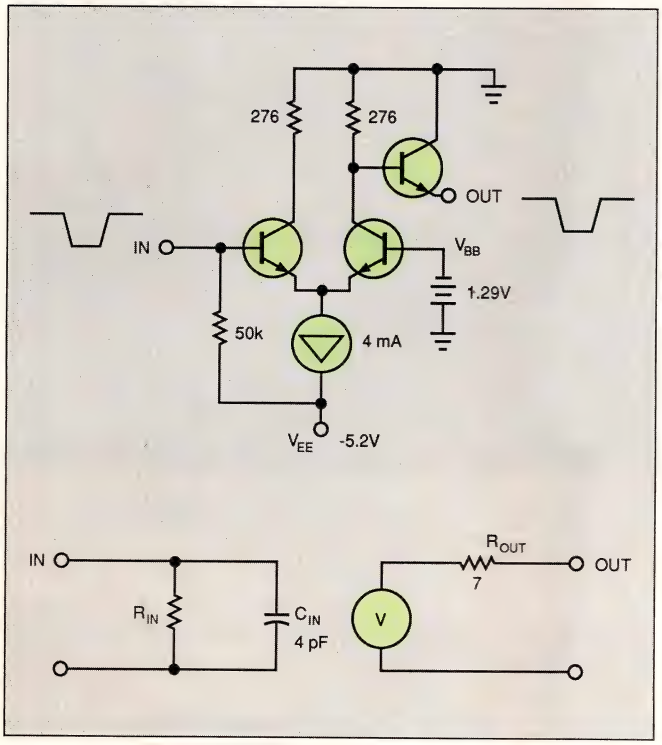


***Fig 3—You can represent an MECL 10KH** gate by this equivalent circuit for simulation purposes.*

and operating frequencies that make transmission-line effects important.

New PC- and workstation-based CAE software programs that address transmission-line effects are now available. Some of them calculate engineering parameters but leave you to interpret their effects. Others, such as Microwave Spice, are simulators derived from Spice that also include accurate models of transmission lines and high-speed digital circuit elements. These programs make it relatively easy for the digital designer to evaluate high-speed board problems and decide on corrective action (**Refs 1, 2,** and **3**).

Microwave simulators help you get a handle on many common board problems. For example, if you're building a board with a very high density of interconnections, you'll have to use very narrow board conductors and pack these lines as closely together as possible. However, as the simulator plot of **Fig 1** shows, when conductor widths and spacing become as small as 0.01 in. on a G-10 board 0.30 in. thick, the crosstalk-coupling between two adjacent lines just 6 in. long can be as large as 170 mV. Crosstalk signals of this magnitude are larger than the noise margin in ECL-based circuits and would cause logic errors. Similar crosstalk and transmission-line effects become even more serious when the digital clock rate exceeds 100 MHz and the logic-gate rise times fall below 1 nsec.

You can analyze many high-speed-board transmission-line problems with the aid of a simple coupled-line example (**Fig 2**). Assume that the logic gate at node 1 drives the gate at node 4 through a transmission line of length l and width w. Because the bottom of the board layer is metallized, this path constitutes a microstrip transmission line (**Ref 4**). Such lines are widely used in microwave circuits at frequencies above 1 GHz. To analyze the microstrip line, you must account for the board-layer thickness, h, and its dielectric constant.

The problem here arises because a second transmission line, with nodes 2 and 3, has been placed very close to the first. The second line also has attached logic gates, which, for example, may be quiescent at the time a logic pulse passes from node 1 to node 4. Your concern is that energy from the pulse on line 1 will be coupled to line 2, thereby creating a crosstalk pulse on line 2 that may be sufficient to disturb logic gates attached to the coupled line.

Consider the case where the coupled lines are connected to MECL 10KH drivers and receivers (**Fig 2**). For simulation purposes, you can represent the MECL gate with a detailed equivalent circuit (**Fig 3**).

The nominal MECL voltage levels are −0.9V for the logic high and −1.8V for the logic low; typical logic rise and fall times are near 1.8 nsec for the 10KH family. The simulation of **Fig 1** also used those values.

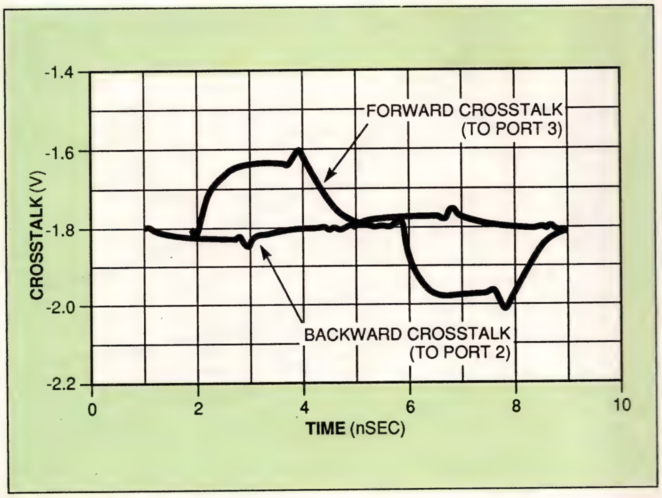


Fig 4—These crosstalk waveforms *are typical of crosstalk measured between coupled lines connecting MECL 10KH logic gates. The hardware used the same line and board dimensions as the simulation of* ***Fig 1****.*

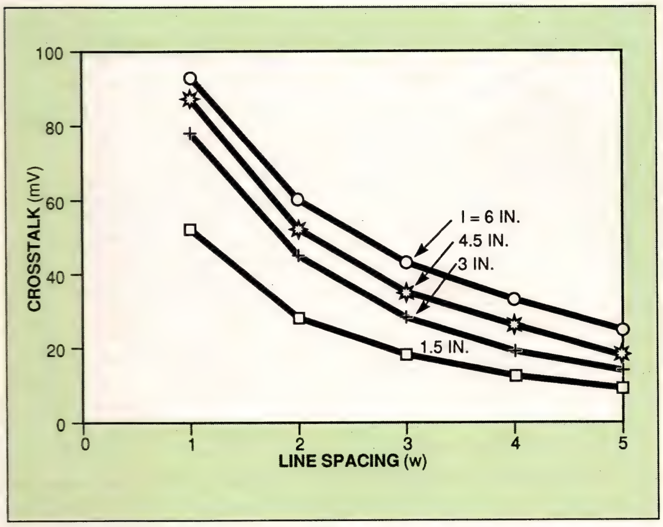


Fig 5—Crosstalk is a function of coupled-line spacing and length. *This simulation is based on the MECL 10KH configuration shown in* ***Fig 2****. Rise time is 1.8 nsec. Board thickness is 0.015 in., and dielectric constant is 4.7.*

Because the noise margin for this logic family is 150 mV, any crosstalk pulses of more than 100 mV will cause problems. For the circuit shown in **Fig 2**, the crosstalk signals that appear at ports 2 and 3 will typically have waveforms similar to those of the simulation shown in **Fig 4**.

Spice-derived simulators use straightforward net-list commands, which are consistent with other Spice products. Once you've used the net lists to enter the configuration of transmission lines and attached logic circuitry, it then becomes a simple matter to run a series of "what-if" simulations to evaluate a wide variety of crosstalk and reflection problems. These simulations will quickly show you the effects caused by changing the logic circuit or the coupled-line dimensions and spacing.

Pulses on two adjacent transmission-lines will always couple to some extent, and the magnitude of coupling is dependent on five main factors:

- Line-to-line spacing
- Length of coupling
- Characteristic impedance of the lines
- Digital-logic rise time
- Effective impedance at line ends.

A series of simulations, based on the circuit of **Fig 2**, indicates the dependence of the crosstalk signal voltage on the length and width of the coupled microstrip pair. The curves in **Fig 5** show the variation of crosstalk

Pulses on two adjacent transmission lines will always couple to some extent; the amplitude of the resulting crosstalk depends on five parameters.

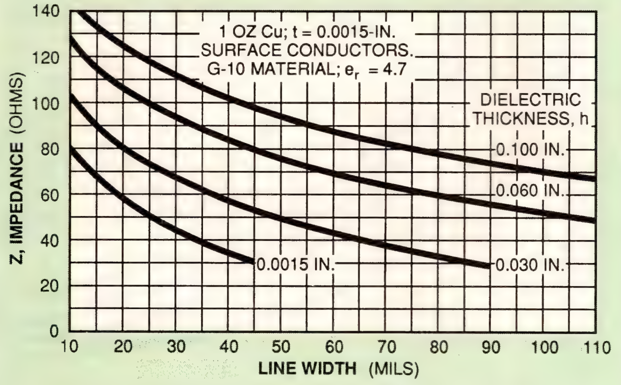


***Fig 6—These curves show characteristic line impedance versus line width** for various thicknesses of G-10 board of dielectric constant 4.7. (Courtesy Motorola MECL System Design Handbook, 1988)*

voltage at node 4 as a function of line separation. These curves assume a transmission-line impedance of 75Ω and show the crosstalk for line lengths varying from 1.5 through 6 in. and line separation normalized in multiples of line width, w. The worst case occurs when the lines are most closely spaced and have greatest length: Six-in. lines separated by one line width (w) generate a crosstalk signal voltage of about 90 mV. The curves show that if you want to limit crosstalk to 50 mV, you'll need to separate lines longer than 3 in. by 3w or more.

Crosstalk is also a function of the characteristic transmission-line impedance (Z_0) of the coupled interconnections. Factors other than crosstalk enter into selecting the impedance of interconnections, but practical choices fall in the range 50 to 100Ω. For MECL logic, the most common values are 68Ω and 75Ω. **Fig 6** shows curves of characteristic impedance (Z_0) versus line width for a range of thicknesses of G-10 board with dielectric constant of 4.7. The lower Z_0 values correspond to relatively wide lines which, in most cases, consume too much board area. Also, a lower Z_0 corresponds to a lower loading resistance, which in turn produces higher currents; hence the logic consumes more power. On the other hand, lines with higher Z_0 restrict the amount of switching current available, and therefore result in proportionately slower switching times.

Two other considerations are relevant to high Z_0 lines. First, the smaller line widths associated with higher Z_0 lead to higher resistive losses in the lines. Second, the narrow lines required are hard to manufacture except on thicker circuit boards. For example, assuming that 10 mils is the narrowest line width that can be satisfactorily controlled, then you'd need a G-10 board thickness of at least 30 mils to achieve a Z_0 of 100Ω. For this reason, lines with Z_0 greater than 100Ω are rarely considered in microstrip.

Crosstalk as a function of line impedance

The simulation output curves in **Fig 7** show the relationship between the line impedance and the crosstalk. Normally, the board thickness is fixed and you change the microstrip characteristic impedance by varying the line width. The curves show the crosstalk resulting from line widths that yield characteristic impedances of 50, 75, and 100Ω, and line spacing equal to 11 mils. To achieve these impedances, the board thickness, h, was varied to 6.3, 15, and 30 mils, corresponding to the same series of impedance values.

Each increase in the impedance of the lines dramatically increased the crosstalk. The calculated crosstalk signal produced on the 3-in., 100Ω line pair, with a separation of one linewidth (1w), is almost 150 mV—almost at the logic upset level for MECL 10KH devices. Also, at line separations of 2w or greater, going from the 75Ω to the 100Ω characteristic impedance more than doubles the crosstalk voltage. Likewise, going from 75Ω lines to 50Ω lines reduces the crosstalk to less than half of the 75Ω value.

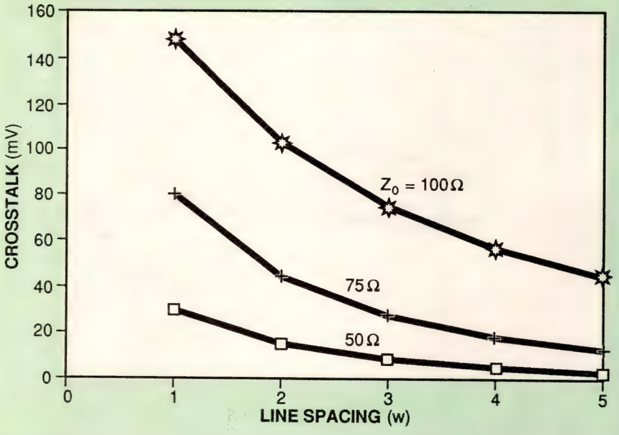
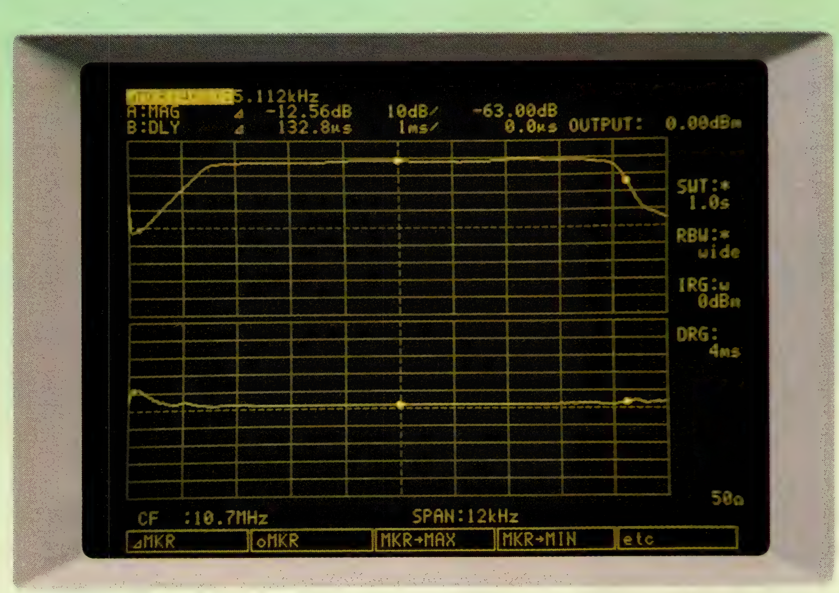


***Fig 7—Crosstalk varies with the characteristic impedance of the coupled lines.** The configuration is the same as that shown in **Fig 2**; the length of the coupled lines is 3 in. Rise time is 1.8 nsec. Board thickness is varied so that w = 0.011 in. for all characteristic impedances. Dielectric constant is 4.7.*

GET THIS... WITH THIS...

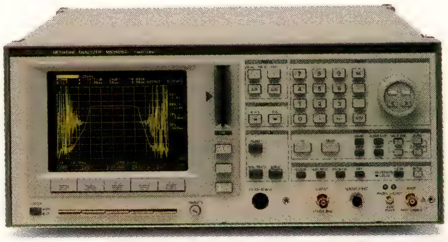


Take Control Of Your VNA, And Get .001 Hz, .01 dB, and .01 Resolution with 120 dB Dynamic Range

- 10 kHz to 1 GHz
- 120 dB Dynamic Range
- Fast—400µs/Point
- Simultaneous Scalar and Vector Analysis
- DDS Source: −80 dBm to +15 dBm in .01 dB Steps

The Anritsu MS3606A Network Analyzer provides unequalled dynamic range and high resolution to measure critical performance specifications of: saw/crystal filters; tuners; UHF/VHF converters, materials and active/passive devices.

For simple fingertip control of your VNA ... literature, application assistance or a demo, contact ... Anritsu America, Inc., 15 Thornton Road, Oakland, NJ 07436. Call 800-255-7234 or (in NJ) 201-337-1111. FAX 201-337-1033



Anritsu

CIRCLE NO. 79

MECL gates can ignore spikes riding on the valid waveform if the spike is shorter than the gates' rise time.

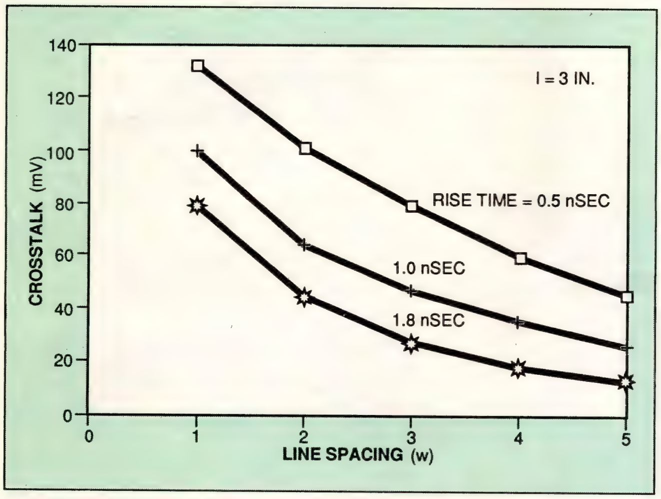


Fig 8—These curves show the effect of the logic-gate rise time on crosstalk *for the MECL 10KH configuration. Coupled-line length is 3 in., rise time is 1.8 nsec, board thickness is 0.015 in., and dielectric constant is 4.7.*

In general, crosstalk coupling increases with faster switching speeds. However, in ECL circuits, the coupling does not increase as fast as you might expect. **Fig 8** shows simulated crosstalk voltage for 3-in. lines as a function of line separation and rise and fall times. If you change the 10 to 90% rise time from 1.8 nsec (typical of the MECL KH10) to 0.5 nsec, the crosstalk voltage increases by less than 20 mV.

The effect of the terminating impedance

Fig 4 shows that the low output impedance (about 7Ω) of the MECL driver reduces the backward-coupled crosstalk signal at port 2 to less than 30 mV. On the other hand, the forward-coupled waveform at port 3 appears across a high-impedance MECL receiver. It can thus reach a peak value near 170 mV, which exceeds the MECL 10KH noise margin and will probably give rise to spurious pulses at the receiver output. However, MECL logic will ignore the short spike riding on the forward signal waveform, because this spike is much shorter than the logic rise time.

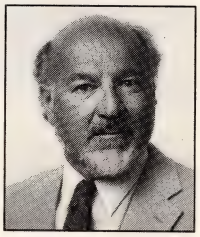
The direction of the valid signal on line 2 is immaterial—if you reverse the positions of the driver and the receiver to be at ports 3 and 2, respectively, you'll also reverse the relative sizes of the forward- and backward-coupled crosstalk signals.

Microwave-simulation software helps you analyze and understand difficult problems in the design of high-speed digital circuits. Because the simulator allows quick analysis of design alternatives, you can find acceptable solutions to coupling problems much faster than you could do by manufacturing a prototype board for diagnostic purposes. In fact, because the software can accurately simulate waveforms at high-impedance nodes where oscilloscope measurements are not practicable, it can provide information that you could not obtain from experimental testing. **EDN**

References

1. Nass, R "PC-Board Speeds Skyrocket," *Electronic Design*, September 28, 1989, pgs 31-38.
2. Gelsinger, P P, et al, "Microprocessors Circa 2000," *IEEE Spectrum* October, 1989, pgs 43-47.
3. Beresford, R, "How to Tame High-Speed Design," *High Performance Systems*, September, 1989, pgs 78-83.
4. Gupta, K C, R Garg, and I J Bahl, *Microstrip Lines and Slotlines*, Artech House, 1979.
5. *Motorola MECL Design Handbook*, HB205 Rev 1, 1988.

Authors' biographies



Octavius Pitzalis, Jr, senior staff scientist at EEsof Inc (Westlake Village, CA), has been involved primarily in microwave circuit design for most of his career. From 1978 to 1987 he worked at the Hughes Research Laboratories in Malibu, CA. Prior to 1978, he was at the US Army Research and Development Laboratories (now called LABCOM) at Fort Monmouth, NJ. He holds a BS from the University of Missouri and is a member of the IEEE.

Tom Reeder is vice president of marketing at EEsof Inc. He has 25 years experience in high-frequency circuit research, development, and marketing—a career that began with a PhD in Electrical Engineering from Stanford University. His outside activities include singing, hiking, and reading.

Article Interest Quotient (Circle One)
High 497 Medium 498 Low 499

National Semiconductor

Take a look at National's new RS-485 quad transceiver.

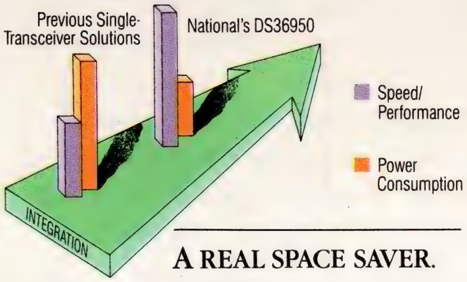
THE INDUSTRY'S FIRST AND ONLY RS-485 QUAD TRANSCEIVER GETS TO ALL POINTS FASTER.

National's new DS36950 sets the standard for multipoint bus transmission. It meets and exceeds RS-485, IPI, and SCSI standards, and is ideal for high-speed, parallel, multi-point, computer I/O bus applications.

In IPI systems, the DS36950 transmits information at speeds that sizzle, displaying data-transfer rates as high as 10 Megatransfers per second on a 13-ns signal transition time.

What's more, it has a typical driver propagation delay time of 13 ns, with guaranteed minimum and maximum propagation delay times that eliminate timing uncertainty across a parallel interface.

The DS36950 achieves higher speeds and consumes less power than previous multiple-chip solutions.



A REAL SPACE SAVER.

With a footprint that's 60% smaller than previous DIP solutions and 20% less than SOIC solutions, the DS36950 comes in a compact 20-pin surface-mount PCC (Plastic Chip Carrier) package. As a result, you get a higher level of transceiver integration and an incredible savings in board space.

STINGY ON POWER.

Boasting a 50% improvement over prior options, the DS36950 consumes less than 20 mA per transceiver. Which makes it well suited for a variety of applications, including:

• Computers • Telecommunications •
• Workstations • Laser printers •
• Optical disk drives • FAX machines •
• Hard disk drives •

WE'RE DRIVING THE STANDARDS.

National has long been a proactive player in setting today's standards. In fact, we participate in a number of committees, including SCSI (X3T9.2), IPI (X3T9.3), and RS-232/422/485 (EIATR30.2).

Our portfolio of over 260 devices is the most comprehensive in the industry, with a wide range of bipolar and CMOS drivers, receivers, and transceivers. All of which are supported by our dedicated group of experienced product specialists.

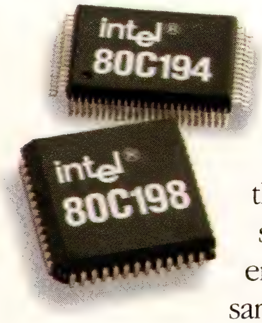
Standards	Dual/Triple Driver	Dual/Triple Receiver	Quad Driver	Quad Receiver	Multi-Channel Line Receivers	Driver/Receiver Pairs	Transceivers/ Repeaters
RS-232	●	●	●	●			
RS-423	●	●					
3601/0	●	●			●		
MIL-188-114		●	●				
RS-422	●	●	●	●		●	●
RS-485			●	●			●
MIL (883)	●	●	●	●			●
IEEE-488							●
BTL							●

SEE FOR YOURSELF.

For free samples and more information, call or write us today: **1-800-624-9613, Ext. 50. In Canada: 1-800-548-4529, Ext. 50. National Semiconductor Corporation, P.O. Box 7643, Mount Prospect, IL 60056-7643.** For high-speed RS-485 multipoint transmission, the DS36950 has the look of a winner.

National Semiconductor

©1990 National Semiconductor Corporation



Choosing an 8- to 16-bit upgrade path can keep you on pins and needles.

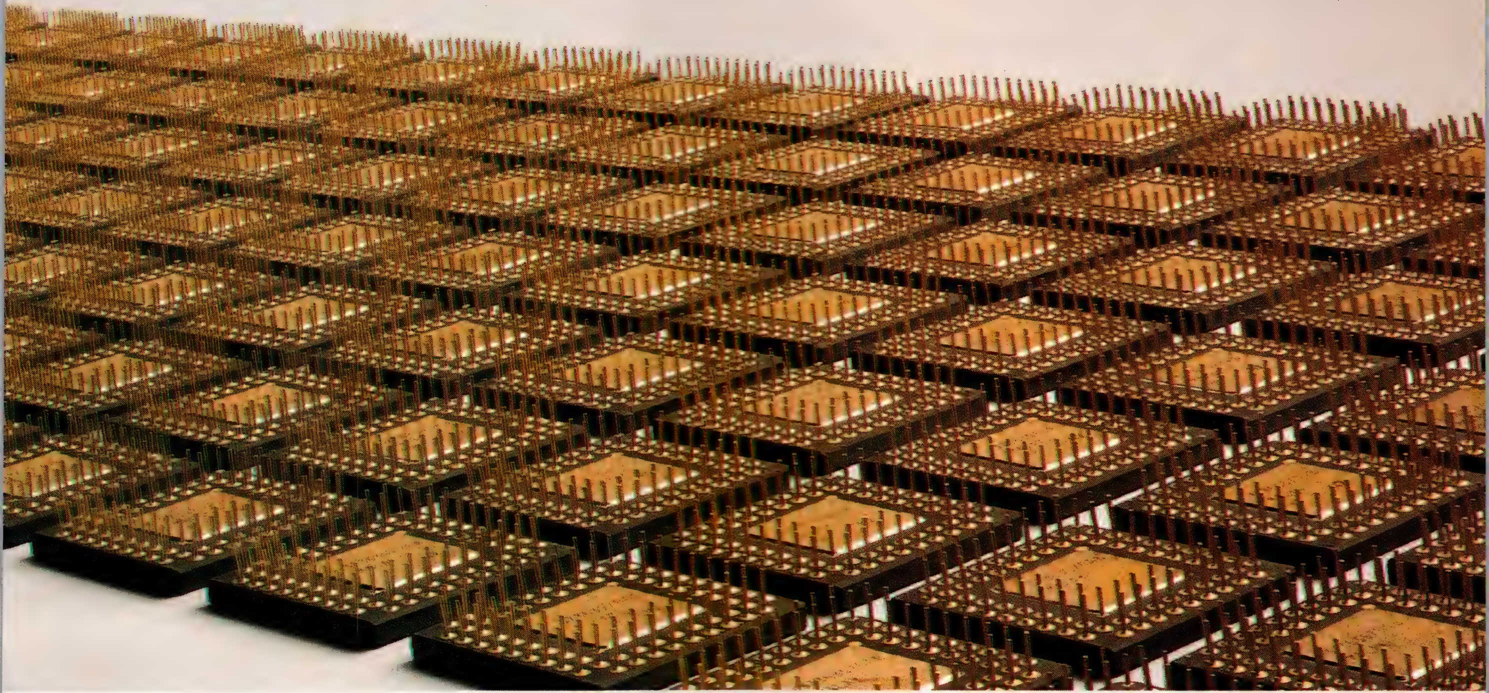
After all, it's a significant step that most designers are taking, since 8-bit performance isn't enough. But no two paths are the same, so it's important to choose a simple, painless solution – Intel's MCS®-96 family.

The 80C194 and 80C198 are the two newest members of Intel's 8096 Microcontroller Family. They let you step up to the higher-performance, 16-bit architecture you need without switching from your 8-bit data bus. And with the 80C194 and 80C198, you're 100 percent compatible with the 15,000,000 MCS-96's already sold. At a price that's competitive with many high-end 8-bit products.

Of course, you still receive the full complement of compilers, assemblers, emulators and evaluation boards that you've come to expect from Intel. And if you're upgrading from the MCS-51 family, you'll receive an industry first to make the transition even easier – our TRANS51-96 converter. It's a new kind of converter that translates the bulk of your

©1990 Intel Corporation

Our 16-bit controller upgrade path avoids many painful steps.



MCS-51 software to MCS-96 instructions.

Only Intel's MCS-96 family offers so many ways to save you time and development costs. Comprehensive training and support programs. A powerful family of fully compatible 16-bit controllers. And exciting, new development tools like ACE196™ software. This first-of-its-kind expert system provides on-line documentation linked with assembly language that virtually eliminates the architectural learning curve.

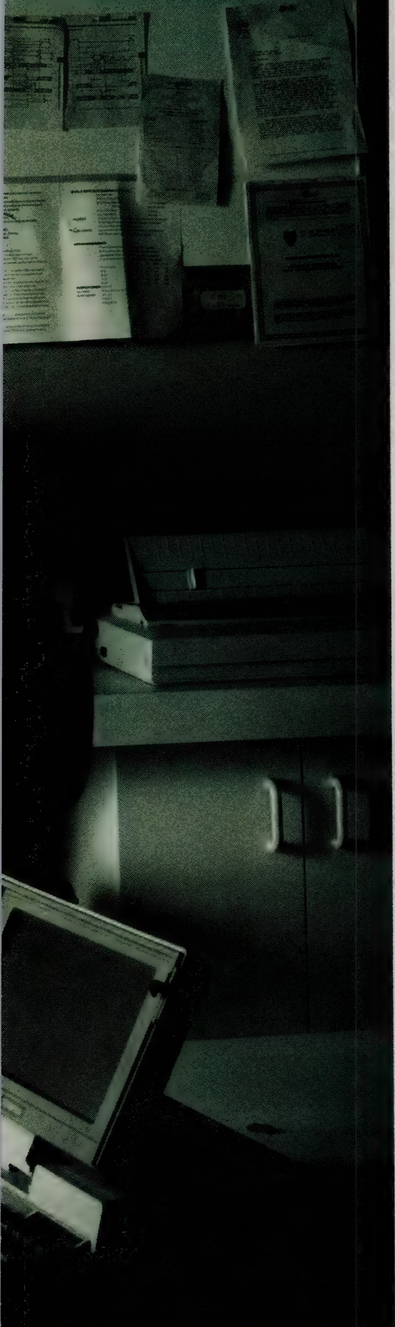
So take the first step to these new levels of performance. Simply call (800) 548-4725 and ask for Literature Department #LA56. We'll send you complete MCS-96 development materials, including the ACE196 expert system and TRANS51-96 code converter. Call before July 31, 1990, and receive yet another first from Intel – a 20 percent discount on MCS-96 training.

Otherwise, you could get stuck on an agonizing upgrade path.

intel®

“What do you think of when I say 4 Megabit DRAM

ALABAMA, Marshall Electronics Group, (205) 881-9235, Milgray Electronics, Inc., (404) 446-9777, Reptron Electronics, (404) 446-1300; **ARKANSAS,** Marshall Electronics Group, (214) 233-5200, Milgray Electronics, Inc., (214) 248-1603, Sterling Electronics-Dallas, (214) 243-1600; **ARIZONA,** Marshall Electronics Group, (602) 496-0290, Sterling Electronics-Phoenix, (602) 437-5565; **CALIFORNIA,** Sterling/Image Electronics, (619) 271-6555, (714) 259-0900, (818) 407-8850, Marshall Electronics Group, (818) 459-5500, (714) 458-5395, (408) 942-4600, (916) 635-9700, (619) 578-9600, Merit Electronics, Inc., (408) 434-0800, Western Microtechnology, (619) 453-8430, (714) 637-0200, (408) 725-1660, (818) 707-0377; **COLORADO,** Marshall Electronics Group, (303) 451-8383, Sterling Electronics-Denver, (303) 792-3939; **CONNECTICUT,** Cronin Electronics, Inc., (203) 265-3134, Marshall Electronics Group, (203) 265-3822, Milgray/Milford (203) 878-6970, Sterling Electronics-Wallingford, (203) 265-9535; **DELAWARE,** General Components, Inc., (609) 768-6767, Marshall Electronics Group, (301) 622-1118, Milgray/Delaware Valley, Inc., (609) 983-5010, (800) 257-7808, (800) 257-7111, Sterling Electronics, (703) 742-8400; **DISTRICT OF COLUMBIA,** Marshall Electronics Group, (301) 622-1118, Milgray/Washington, Inc., (301) 621-8169, (800) 638-6656, Sterling Electronics, (804) 226-2190; **FLORIDA,** Marshall Electronics Group, (813) 573-1399, (305) 977-4880, (305) 767-8585, Reptron Electronics-Tampa, (813) 855-4656, (305) 735-1112; **GEORGIA,** Marshall Electronics Group, (404) 923-5750, Milgray Electronics, Inc., (404) 446-9777, (404) 393-9666, Reptron, (404) 446-1300; **IDAHO,** Marshall Electronics Group, (801) 486-1551, Western Microtechnology, (503) 629-2082, Milgray Electronics, Inc., (801) 272-4999; **ILLINOIS,** Goold Electronics, (708) 860-7171, (708) 593-3220, Marshall Electronics Group, (708) 490-0155, (314) 291-8554, Milgray Electronics, Inc., (913) 236-8800, (708) 253-7212; **INDIANA,** Goold Electronics, (708) 593-3220, Marshall Electronics Group, (317) 297-0483, (612) 559-2211, Milgray/Chicago, Inc., (708) 253-1212, (913) 236-8800; **KANSAS,** Marshall Electronics Group, (913) 492-3121, Milgray Electronics, Inc., (913) 236-8800, Sterling Electronics-Kansas, (913) 492-5406; **KENTUCKY,** Marshall Electronics Group, (513) 898-4480, Milgray/Cleveland, Inc., (216) 447-1520, (214) 248-1603, (800) 321-0006; **LOUISIANA,** Marshall Electronics Group, (214) 233-5200, Milgray Electronics, Inc., (214) 248-1603, Sterling Electronics-Dallas, (214) 243-1600; **MAINE,** Cronin Electronics, Inc., (617) 449-5000, Marshall Electronics Group, (617) 658-0810, Sterling Electronics-Boston, (617) 938-6200, Western Microtechnology, (617) 273-2800; **MARYLAND,** Marshall Electronics Group, (301) 622-1118, (301) 840-9450, Milgray Electronics, Inc., (301) 621-8169, (800) 638-6656, Sterling Electronics-Sterling, (804) 226-2190, (301) 290-3800; **MASSACHUSETTS,** Cronin Electronics, Inc., (617) 449-5000, Marshall Electronics Group, (617) 658-0810, Sterling Electronics-Boston, (617) 938-6200, Western Microtechnology, (617) 273-2800; **MICHIGAN,** Marshall Electronics Group, (313) 525-5850, Reptron Electronics, Inc., (313) 525-2700; **MINNESOTA,** Marshall Electronics Group, (612) 559-2211, Reptron Electronics, (612) 938-0000, Sterling Electronics, (612) 831-2266; **MISSISSIPPI,** Marshall Electronics Group, (205) 881-9235, Milgray Electronics, Inc., (404) 393-9666; **MISSOURI,** Marshall Electronics Group, (314) 291-8554, Milgray Electronics, Inc., (913) 236-8800; **NEBRASKA,** Marshall Electronics Group, (913) 492-3121, Milgray Electronics, Inc., (913) 236-8800;



"There's so much. New applications. New markets. Denser memory for our systems. We could release that design we made last year."

"So what are you waiting for? Get to work."

"You're kidding. Is the 4 Megabit DRAM out? Who's got it?"

"Toshiba. And you. It should be here this afternoon."

They're here all right. 4Mb DRAMs from Toshiba. Just think what you can do with them. You can attack whole new markets. Design new portable and lap-top applications where you've never had room for enough memory. Embedded applications, too, where you're always so cramped for board space.

Here's the best part. You get the 4Mb density without any penalty in power. In fact, they use no more power than a 1Mb DRAM. That means you can upgrade a system without major redesign. It also means your system will run cool, for added reliability.

Or how about that 80ns access time. That means you can design true zero wait-state systems without resorting to cache memory or complex interleaving schemes.

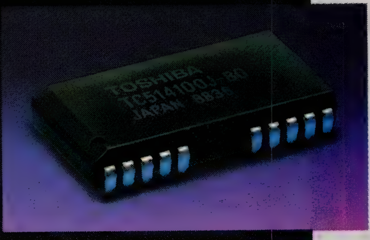
4Mb DRAM SPECIFICATIONS		
	4M x 1	1M x 4
Access Times	80ns, 100ns	80 ns, 100ns
Operating Power	550mW, 468mW	578mW, 495mW
Packaging	ZIP & SOJ	
Modes	Fast Page Nibble Static Column	Fast Page Static Column Write Per Bit

The high density is made possible by our 0.8 micron design rules, and our Twin Tub CMOS fabrication process. But you'd expect that from the world leader in DRAMs. You'd expect them to be available in all standard JEDEC package and mode options. And they are. You'd expect them to operate on a single 5 volt supply, too. And they do.

But we give you a few things you might not expect. A master slice concept, for instance. That will cut your qualifying costs tremendously. When you qualify one part, you qualify the whole family.

We save you costly testing time, too. The 8-bit parallel test mode lets you test the unit as if it were eight 512K blocks in parallel. That takes only 1/8th of the time. And the test can be done at the component, board or system level. In fact, your customers can test memory every time they power-up.

There's more to tell. Much more. But we've run out of room. If you'd like complete information, give us a call at 1-800-888-0848 ext. 517. We'll drop a data sheet in the first mail. *Service is our key component.*



In Touch with Tomorrow

TOSHIBA

TOSHIBA AMERICA ELECTRONIC COMPONENTS, INC.

©1989 Toshiba America Electronic Components, Inc.

MST-89-014-1

NEVADA, Marshall Electronics Group, (916) 635-9700, (602) 496-0290, Sterling Electronics, (602) 437-5565, Western Microtechnology, (408) 725-1660. **NEW HAMPSHIRE**, Cronin Electronics, Inc., (617) 449-5000, Marshall Electronics Group, (617) 658-0810, Sterling Electronics-Boston, (617) 938-6200, Western Microtechnology, (617) 273-2800; **NEW JERSEY**, General Components, Inc., (609) 768-6767, Marshall Electronics Group, (201) 882-0320, (609) 234-9100, Milgray Electronics, Inc., (609) 983-5010, (800) 257-7808, (800) 257-7111, Sterling Electronics-So. Plainfield, (201) 769-7000; **NEW MEXICO**, Marshall Electronics Group, (602) 496-0290, Sterling Electronics-Albuquerque, (505) 884-1900; **NEW YORK**, Marshall Electronics Group, (516) 273-2424, (607) 798-1611, (716) 235-7620, Milgray Electronics, Inc., (516) 420-9800, (716) 235-0830, Rome Electronics, (315) 337-5400; **NORTH/SOUTH CAROLINA**, Marshall Electronics Group, (919) 878-9882, Milgray Electronics, Inc., (404) 393-9666, Resco Raleigh, (919) 781-5700; **NORTH/SOUTH DAKOTA**, Marshall Electronics Group, (612) 559-2211, Reptron Electronics, (612) 938-0000. **OHIO**, Marshall Electronics Group, (513) 898-4480, (216) 248-1788, Milgray/Cleveland, Inc., (216) 447-1520, (800) 321-0006, Reptron Electronics, (614) 436-6675, (216) 349-1415; **OKLAHOMA**, Marshall Electronics Group, (214) 233-5200, Milgray Electronics, Inc., (214) 248-1603, Sterling Electronics-Tulsa, (918) 663-2410. **OREGON**, Marshall Electronics Group, (503) 644-5050, Western Microtechnology, (503) 629-2082; **PENNSYLVANIA**, General Components, Inc., (609) 768-6767, Marshall Electronics Group, (609) 234-9100, (412) 788-0441, Milgray/Cleveland, Inc., (216) 447-1520, (800) 257-7808, (800) 257-7111; **RHODE ISLAND**, Cronin Electronics, Inc., (617) 449-5000, Marshall Electronics Group, (617) 658-0810, Sterling Electronics-Boston, (617) 938-6200, Western Microtechnology, (617) 273-2800; **TENNESSEE**, Marshall Electronics Group, (205) 881-9235, Milgray Electronics, Inc., (404) 393-9666, Resco Raleigh, (919) 781-5700; **TEXAS**, Marshall Electronics Group, (214) 233-5200, (915) 593-0706, (713) 895-9200, (512) 837-1991, Milgray Electronics, Inc., (214) 248-1603, (713) 240-5360, Sterling Electronics, (713) 623-6600, (512) 836-1341, (214) 243-1600, Western Microtechnology (214) 416-0103; **UTAH**, Marshall Electronics Group, (801) 485-1551, Milgray Electronics, (801) 272-4999, Sterling Electronics, (801) 972-5444, (303) 792-3939; **VERMONT**, Cronin Electronics, Inc., (617) 449-5000, Marshall Electronics Group, (617) 658-0810, Sterling Electronics-Boston, (617) 938-6200, Western Microtechnology, (617) 273-2800; **VIRGINIA**, Marshall Electronics Group, (301) 840-9450, Sterling Electronics, (703) 742-8400, (804) 226-2190; **WASHINGTON**, Marshall Electronics Group, (206) 486-5747, Western Microtechnology, (206) 881-6737; **WISCONSIN**, Goold Electronics, (708) 860-7171, Marshall Electronics Group, (414) 797-8400, (414) 475-6000, Milgray, (708) 253-1212, Reptron Electronics, (612) 938-0000; **CANADA**, Marshall Electronics Group, (416) 458-8046, ITT Multicomponents, (604) 291-8866, (403) 273-2780, (204) 786-8401, (416) 736-1144, (613) 596-6980, (514) 335-7679, (902) 465-2350, Active Components, (514) 697-8676, (416) 636-8814, (613) 596-5340, (604) 294-1166.

CIRCLE NO. 81

Emulation power without compromise

EZ-Pro™ 1.5 price performance leader for 8-bit in-circuit emulation.

EZ-Pro 2.1 industry workhorse for 16-bit and 8-bit designs.

Power in selection—System support for more processors than any other manufacturer in the world. Power in product range to match your needs—from economical basic configurations to fully featured systems.

Power in performance—Completely integrated capabilities include options such as versatile trace, performance analysis, EPROM programming, C source level debugging, over 100 personality modules with a common universal platform for different processors, C cross compilers, cross assemblers and more.

Power without compromise—All invented here. Supported here. And available to rent or purchase now.

Free Demo Disk!

See how easily you can use these sophisticated development tools. Our marketing department will ship your demo disk today. Please Call:

(714) 731-1661

american automation **Headquarters:** 2651 Dow Avenue, Tustin, California 92680-7207 Telephone (714) 731-1661. **European Headquarters:** UK Oxford 993 778991. **Distributors:** Australia 3-5601011, Belgium 2-4681400, France 1-69308050, India 418387, Indonesia 22-71880, Italy 2-50722282, Korea 2-7849942, Spain 1-7291155, Switzerland 1-4354111, Taiwan 2-7368150, West Germany 89-6127087.

EZ-Pro is a trademark of American Automation Inc.

CIRCLE NO. 82

DESIGN IDEAS

EDITED BY ANNE WATSON SWAGER

Capacitor boosts amplifier bandwidth

Jonathan Audy
Precision Monolithics, Santa Clara, CA

Current-feedback op amps theoretically feature a constant bandwidth-vs-gain curve, but theory never completely holds true. A current-feedback amplifier's gain does roll off, especially at gains greater than 5 or under heavy load conditions. You can improve the bandwidth and phase margin of a current-feedback op amp by placing some gain-compensating capacitance, C_C, across the gain-set resistor, R_G **(Fig 1a)**. This technique won't work on a voltage-feedback amplifier because its gain-bandwidth product limits the transfer function. Any attempt to boost the gain would be countered by more bandwidth roll-off.

You can derive an equation for the value of C_C with the aid of the equivalent circuit of a current-feedback op amp **(Fig 1b)**. The −6-dB point is the frequency where the output signal halves in amplitude; you can measure the circuit's −6-dB bandwidth with a network analyzer or a signal generator and oscilloscope. The effective value of R_G at the −6-dB point is

$$R_{G(-6\text{ dB})}=\frac{R_G}{2\pi f R_G C_G+1},$$

where f is the −6-dB frequency, R_F is the feedback resistance, R_G is the gain-set resistance, and C_G is the stray capacitance. The effective value of R_G at the −6 dB frequency required to boost the gain back to 0 dB is

$$R_{G(0\text{ dB})}=\frac{R_F}{1+2R_F/R_{G(-6\text{ dB})}}.$$

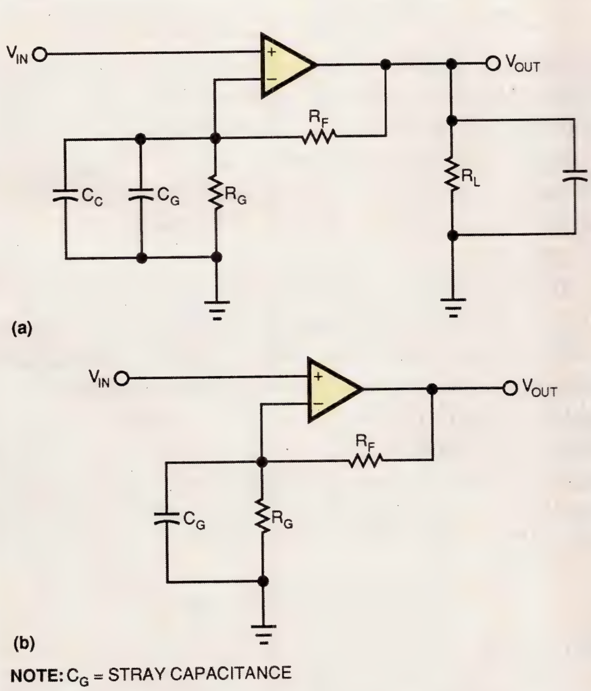


*Fig 1—An additional capacitor, C_C, across gain-set resistor R_G **(a)** boosts the bandwidth of a current-feedback amplifier. Equations derived from the amplifier's equivalent circuit **(b)** will help you choose the appropriate value of C_C.*

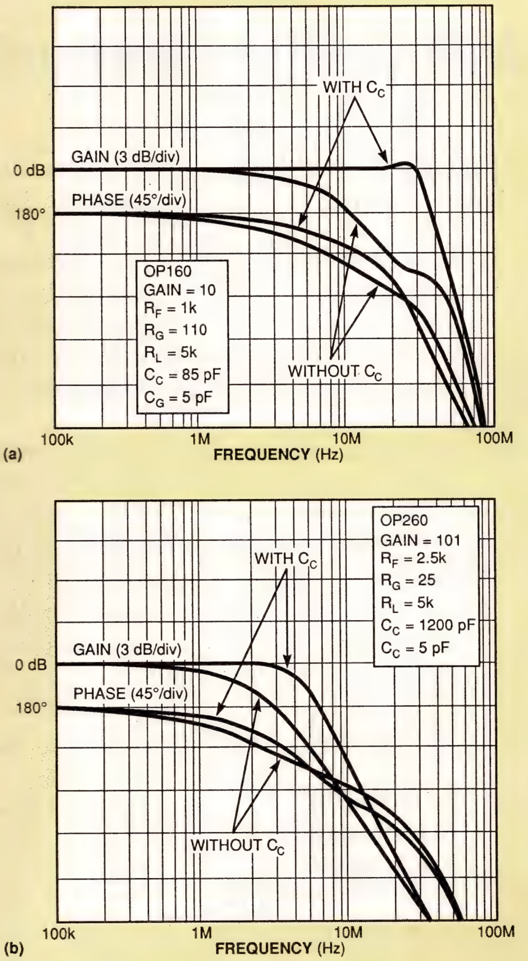


*Fig 2—**Gain and phase plots** of two different current-feedback amplifiers at different gain settings demonstrate the improvement offered by C_C.*

If you now consider that C_C is in parallel with R_G, you can derive an equation for $R_{G(0\ dB)}$ from $R_{G(-6\ dB)}$:

$$R_{G(0\ dB)}=\frac{R_G}{2\pi f R_G(C_G+C_C)+1}.$$

Combining these equations and solving for C_C yields:

$$C_C=C_G+\frac{1}{2\pi f R_G}+\frac{1}{2\pi f R_F}.$$

This equation applies to positive gains and closely agrees with actual circuit performance (**Fig 2**). The following equation applies to negative gain configurations:

$$C_C=C_G+\frac{1}{2\pi f R_G}.$$

EDN

To Vote For This Design, Circle No. 744

TMS32010 routine finds phase

Derek McKee
Marconi Instruments, By Dunfermline, Scotland

Engineers often want to know the magnitude and phase of a signal, but an FFT yields only the real and imaginary components of that signal. Calculating the phase of a signal is more problematic than computing its magnitude because the phase calculation involves the arctangent function.

These polynomial approximations for the arctangent function (**Ref 1**) are faster and take up less memory than look-up-table schemes because they take advantage of the TMS32010 DSP µP's hardware multiplier.

Chebyshev economization reduces the **Ref**'s 6-term arctangent approximation, which is more precise than necessary, to 5-term and 4-term approximations for the first octant:

$$\arctan(x)=b_1x+b_3x^3+b_5x^5+b_7x^7+e(x),$$

where $b_1=0.999134$,
$b_3=-0.320533$,
$b_5=0.144982$,
$b_7=-0.038254$, and
$e(x)\leq 10^{-4}$ rad

and

$$\arctan(x)=c_1x+c_3x^3+c_5x^5+e(x),$$

where $c_1=0.994950$,
$c_3=-0.287061$,
$c_5=0.078037$, and
$e(x)\leq 10^{-3}$ rad.

Simulator testing of the TMS32010 assembly language for these algorithms yielded a ±1-LSB accuracy. Note that normally a small amount of arithmetic noise is present in the results of any FFT. You must treat this noise carefully to avoid erroneous results. For example, because of the finite word length of the DSP µP's registers, you could obtain (0,1), (1,1), or (−1,0) for the same point on a clean sine wave.

To obtain TMS32010 subroutines that handle all four quadrants and check for noise, send a stamped, self-addressed envelope to Derek McKee, Marconi Instruments, Dewar Building, Hillend Industrial Estate, Hillend, By Dunfermline, Fife, KY11 5JZ, Scotland. (Include enough postage to get your envelope from Scotland to your address.) Phone 0383 822131. FAX 0383 824220.

EDN

Reference

1. Abramowitz, Milton and Irene Stegun, *Handbook of Mathematical Functions*, Dover Publications, New York, NY.

To Vote For This Design, Circle No. 745

SPDT & SP4T SWITCHES

WITH BUILT-IN DRIVERS

10 to 3000MHz from \$39^{95}

Now, high-speed, high-isolation switches with built-in drivers, tough enough to pass stringent MIL-STD-202 tests. There's no longer any need to hassle with the complexities of designing a TTL driver interface and then adding yet another component to your subsystem…it's already included in a rugged, low-cost, compact assembly.

Available in the popular hermetically-sealed TO-8 package or a small EMI-shielded metal connectorized case, these tiny PIN-diode reflective switches, complete with driver, can operate over a 10 to 3000MHz span with a fast 2μsec switching speed.

Despite their small size, these units offer isolation as high as 40dB(typ), insertion loss of only 1.1dB(typ), and a 1dB compression point of +27dBm over most of the frequency range. All models are TTL-compatible and operate from a dc supply voltage of 4.5 to 5.5 V with 1.8mA quiescent current.

Switch to Mini-Circuits for highest quality innovative products…and leave the driving to us.

SPECIFICATIONS

	TOSW-230 ZSDR-230		TOSW-425 ZSDR-425	
Freq. Range(MHz)	10-3000		10-2500	
Insert. Loss (dB)	typ.	max.	typ.	max.
10-100MHz	1.3	**1.9**	1.3	1.7
100-1500MHz	1.1	**1.9**	1.1	1.7
1500-3000MHz	1.8	**2.7**	1.8	2.5
Isolation(dB)	typ.	min.	typ.	min.
10-100MHz	60	40	60	40
100-1500MHz	40	**28**	40	30
1500-3000MHz	35	22	35	22
1dB Compression(dBm)	typ.	min.	typ.	min.
10-100MHz	17	6	17	6
100-1500MHz	27	19	27	19
1500-3000MHz	30	28	30	28
VSWR(ON)	typ.	max.	typ.	max.
	1.3	1.6	1.3	1.6
Switching Time (μsec) (from 50% TTL to 90% RF)	typ.	max.	typ.	max.
	2.0	4.0	2.0	4.0
Oper. Temp.(°C)	-55 to +100		-55 to +100	
Stor. Temp.(°C)	-55 to +100		-55 to +100	
Price (10-24)	**$39.95**		**$59.95**	
(1-9)	$89.95		$109.95	

finding new ways…
setting higher standards

Mini-Circuits
A Division of Scientific Components Corporation
P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500
Fax (718) 332-4661 Domestic and International Telexes: 6852844 or 620156

WE ACCEPT AMERICAN EXPRESS

CIRCLE NO. 83

F126 REV.A

Programmable pulser takes 5-nsec steps

Robert A Pease
National Semiconductor Corp, Santa Clara, CA

The pulse generator in **Fig 1** lets you program pulse widths of 50 to 15,000 nsec with a resolution of 5 nsec. The circuit parallel-loads a ripple counter with an N-bit word using a slow CMOS counter, F100124 TTL-to-ECL level changers, and F10102 NOR gates. When the start-pulse command goes active, the counter starts a pulse and ends it 5×N nsec later, where N is the decimal equivalent of the counter's preset binary value.

The ripple counter consists of a string of F100131

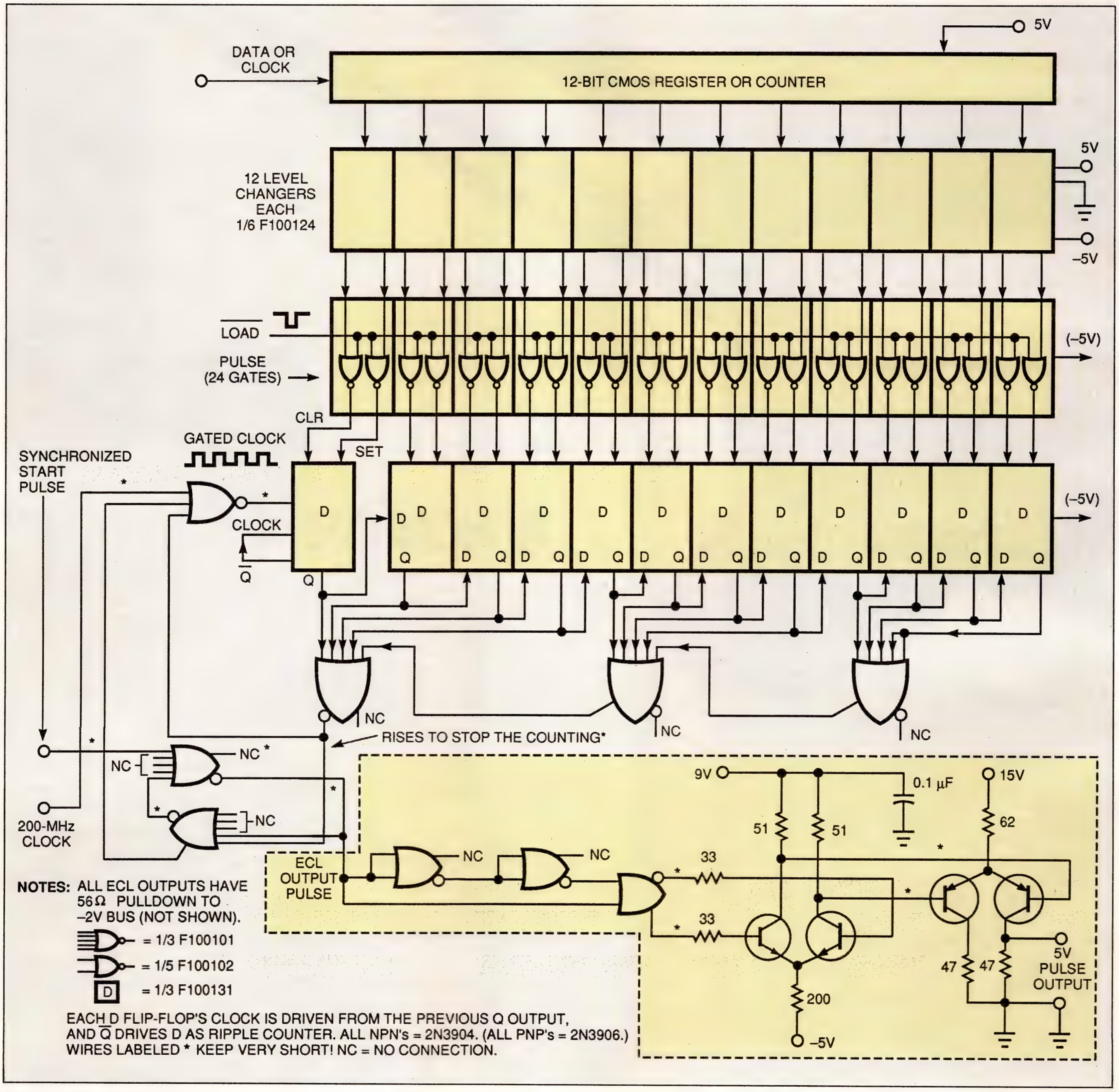

5V
DATA OR CLOCK
12-BIT CMOS REGISTER OR COUNTER
5V
12 LEVEL CHANGERS EACH 1/6 F100124
–5V
LOAD
PULSE (24 GATES)
(–5V)
CLR
GATED CLOCK
SET
SYNCHRONIZED START PULSE
*
*
CLOCK
Q̄
Q
D
D
Q
(–5V)
NC
NC
NC
RISES TO STOP THE COUNTING*
NC *
NC
*
*
200-MHz CLOCK
NC
9V
0.1 μF
15V
51
51
62
NC
NC
33
*
ECL OUTPUT PULSE
*
*
33
47
47
5V PULSE OUTPUT
200
–5V
NOTES: ALL ECL OUTPUTS HAVE 56Ω PULLDOWN TO –2V BUS (NOT SHOWN).
= 1/3 F100101
= 1/5 F100102
D = 1/3 F100131
EACH D FLIP-FLOP'S CLOCK IS DRIVEN FROM THE PREVIOUS Q OUTPUT, AND Q̄ DRIVES D AS RIPPLE COUNTER. ALL NPN's = 2N3904. (ALL PNP's = 2N3906.)
WIRES LABELED * KEEP VERY SHORT! NC = NO CONNECTION.

Fig 1—This high-speed pulse generator *uses a fast ECL counter and a fast clock to create pulses of 50 to 15,000 nsec.*

Actual size

Actual output

20 WATTS

Actually meets

MIL-STD-2000
MIL-STD-810C
MIL-S-901C
MIL-STD-461C
MIL-STD-704D
NAVMAT GUIDELINES

Mil/Pac™ high-density military power supplies. Introducing NDI DC-to-DC converters that meet an unprecedented combination of military design demands. Plus having the highest power-to-volume ratios of any full-mil qualified products.

Mil/Pacs come in 20W, 35W and 50W configurations, with single (5, 12, 15, 24, 28V) and dual (±12V; ±15V) outputs.

They handle a wide 14V to 31V range of input. And operate at temperature extremes from −55°C to +100°C.

Mil/Pacs are designed with a field-proven topology that's been verified by rigorous environmental stress screening. They're available with MIL-STD-2000, or without. Either way, the specs are worth reading.

Just write us at 2727 S. La Cienega Bl., Los Angeles, CA 90034. Or call (213) 936-8185.

abbott

WHEN RELIABILITY IS IMPERATIVE.™

CIRCLE NO. 84

D flip-flops. The chain of D flip-flops works better than commercially available synchronous flip-flops because D flip-flops have smaller delays to the first Q output, which permits faster clocking. Twelve flip-flops, or 4 packages of F100131s, provide a resolution of 1 part in 4095. The number of bits that the circuit can resolve has no practical limit because the end of the ripple counter is not part of the critical path.

For the circuit to produce a pulse of exact width, you need to synchronize the clock with the start pulse (**Fig 2**). Using this circuit, the counter's output pulse is synchronous with the 200-MHz clock, not with the start pulse. Discrete-transistor level changers convert the ECL output pulse first to a 9V level and then down to a 5V level that is suitable for driving the input of any TTL logic gate.

Counter/timer instruments measured the pulse width of the signals in **Fig 3** to greater than 0.1% accuracy and repeatability. The signals' rise and fall times are about 2.5 nsec. The output pulse settles to 0.2% in about 12 nsec. The differential amplifiers that drive the output are the main settling-time limitation.

The layout of any fast ECL circuit is critical. You should arrange the ICs so that the total circuit path from the flip-flop to the first and then second gate is no more than 1.2 in. Point-to-point wiring with a small amount of ground plane works well. Of course, larger amounts of ground plane would be even better.

To Vote For This Design, Circle No. 746

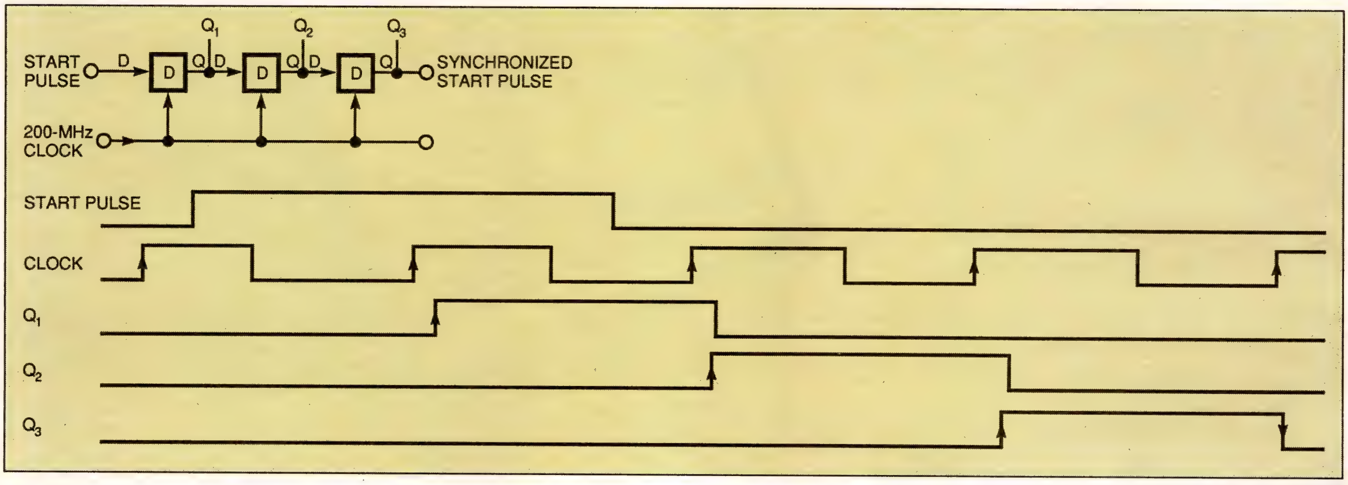


Fig 2—To produce an exact pulse width, *you must first synchronize the start pulse and the 200-MHz clock.*

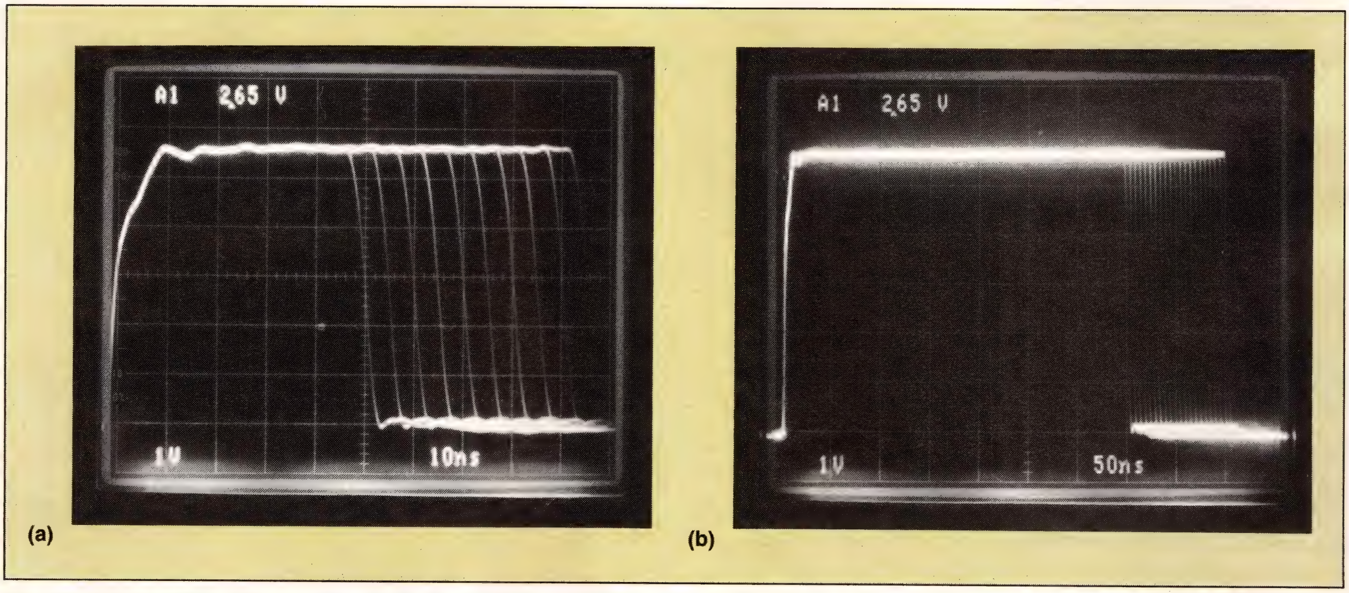
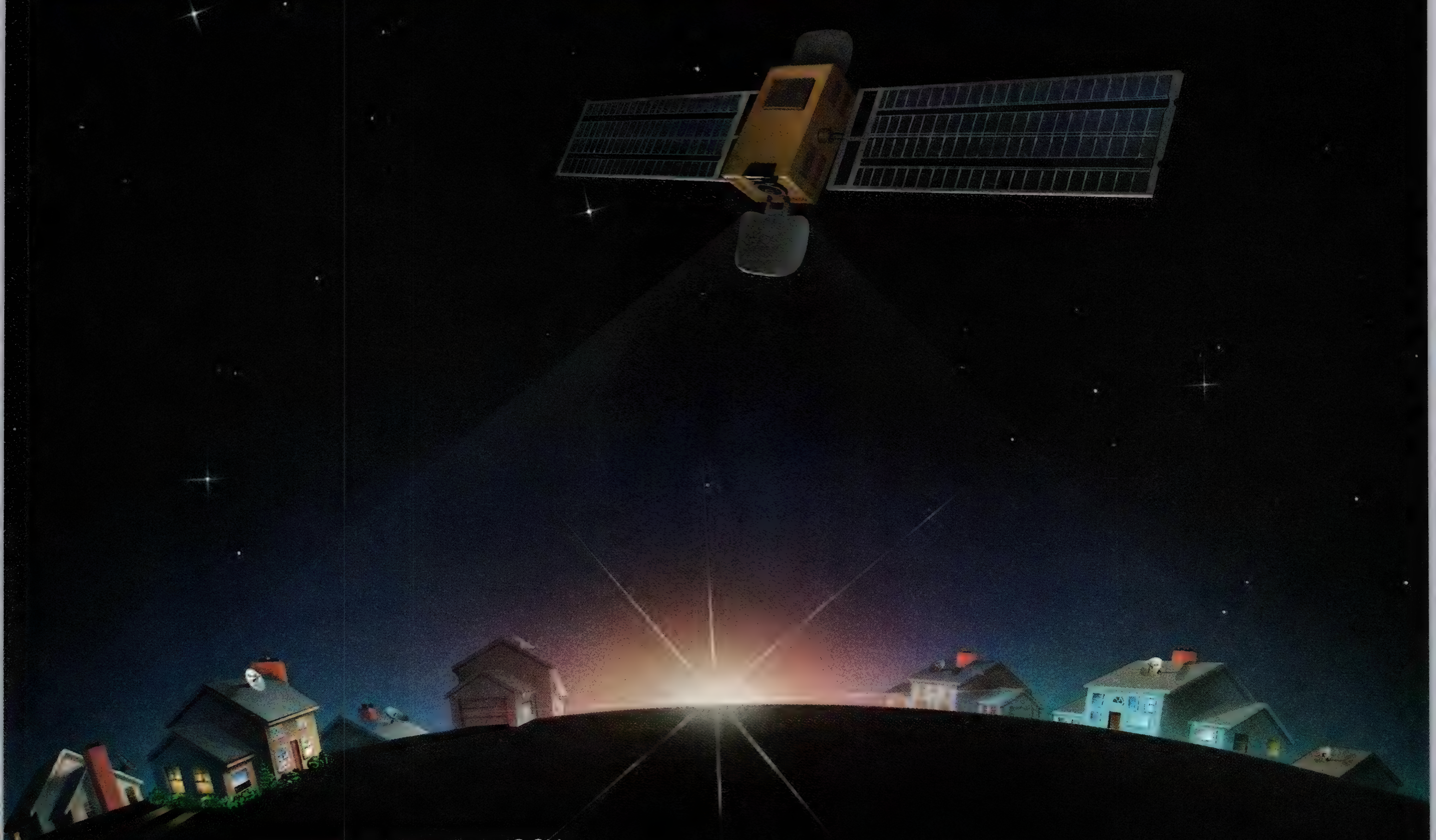
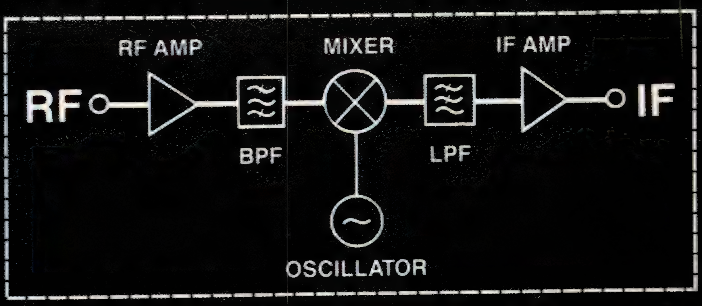


Fig 3—Output pulses varying from 50 to 95 nsec (a) *and from 350 to 450 nsec* ***(b)*** *have greater than 0.1% accuracy and repeatability according to counter/timer measurements. The outputs settle to 0.2% in about 12 nsec because of the limiting action of the differential amplifiers that drive the output.*

NOW! HIGH VOLUME–LOW COST DOWNCONVERTER ICs FOR Ku-BAND SATELLITE DISHES



ANADIGICS Ku-Band GaAs IC Chip



MODEL	BANDWIDTH	APPLICATION
AKD 12000	10.95 - 11.70 GHz	Communications/DBS
AKD 12010	11.70 - 12.20 GHz	DBS
AKD 12011	11.70 - 12.50 GHz	DBS (Full Spectrum)

Off-The-Shelf Delivery

Only ANADIGICS gives you downconverter IC chips for less than $10 each ... in quantities of 100,000 ... immediately! They increase reliability, reduce the number of components, shrink overall downconverter size, and cut your engineering and assembly time. The result? With ANADIGICS, you get to market faster, for less, with unmatched reliability. And we'll give you application assistance or a sample downconverter IC with a fixture ready to hook up to your test bench. Call our Marketing Department today at 201-668-5000 or write to ANADIGICS, 35 Technology Drive, Box 4915, Warren, NJ 07060
FAX 201-668-5068

See Us At MTTS Booth #1422

CIRCLE NO. 85

ANADIGICS®

Your GaAs IC Source

Step-recovery diodes sharpen pulses

Russel Jacob Baker
EG&G Energy Measurements, Las Vegas, NV

The circuit in **Fig 1** uses step-recovery diodes to generate 40V, 1-nsec pulses. The diodes act like charge-controlled switches. When stored charge exists in the junction of a diode, the diode's impedance is typically less than 1Ω. With no stored charge, the diodes exhibit high impedance.

Under steady-state conditions, SRD_1 and SRD_2 are forward-biased and store charge. When you apply an input signal, such as that generated by the circuit in **Fig 2**, SRD_1 starts to discharge and holds the impedance shunting the load to less than 1Ω. The diode switches to a high-impedance state when it reaches full discharge. Since the impedance of SRD_2 is still very low, the majority of the output voltage drops across the 50Ω load resistor, R_{LOAD}. When SRD_2 loses its charge, it switches to a high-impedance state. Then the majority of the input voltage drops across SRD_2.

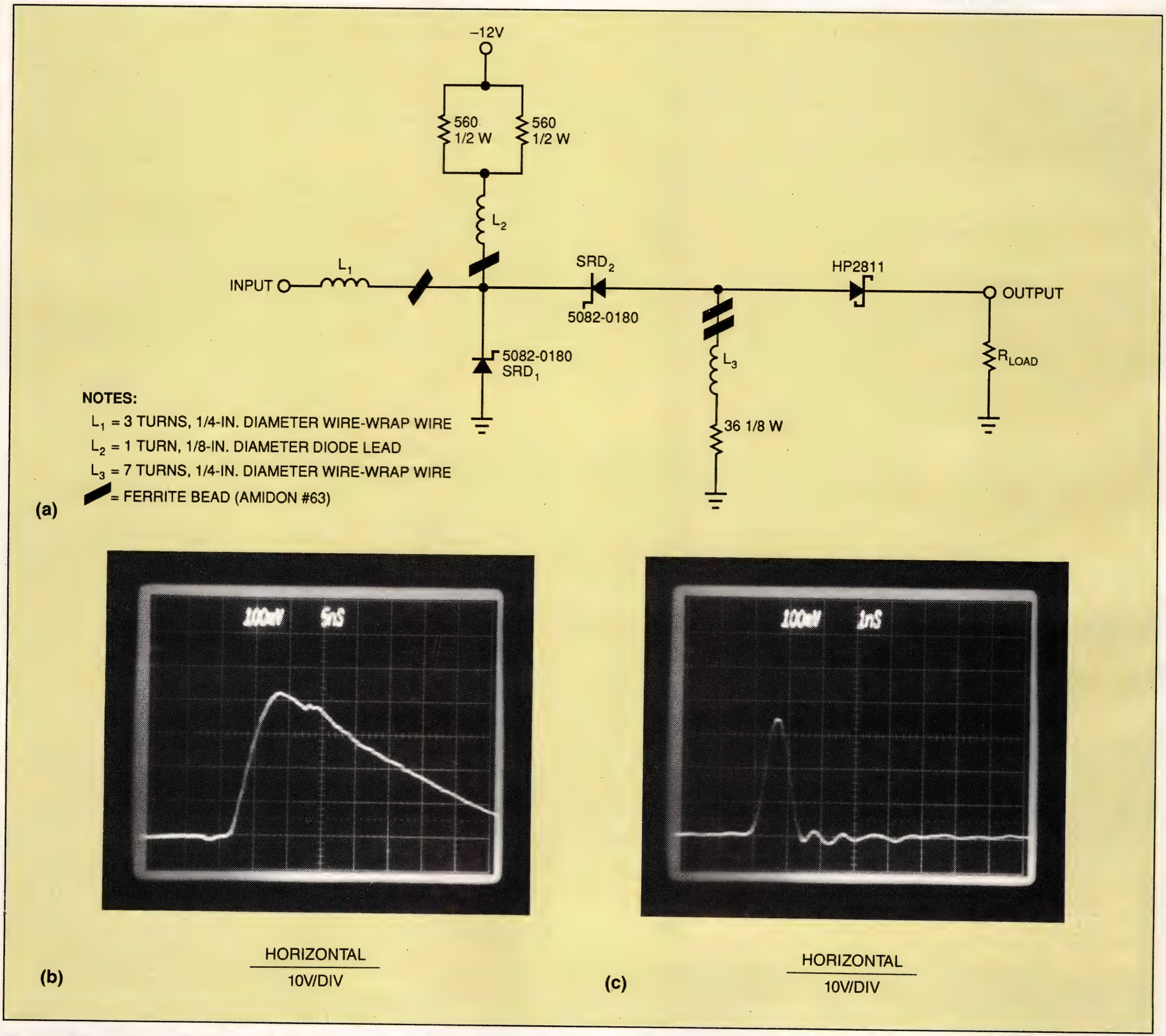
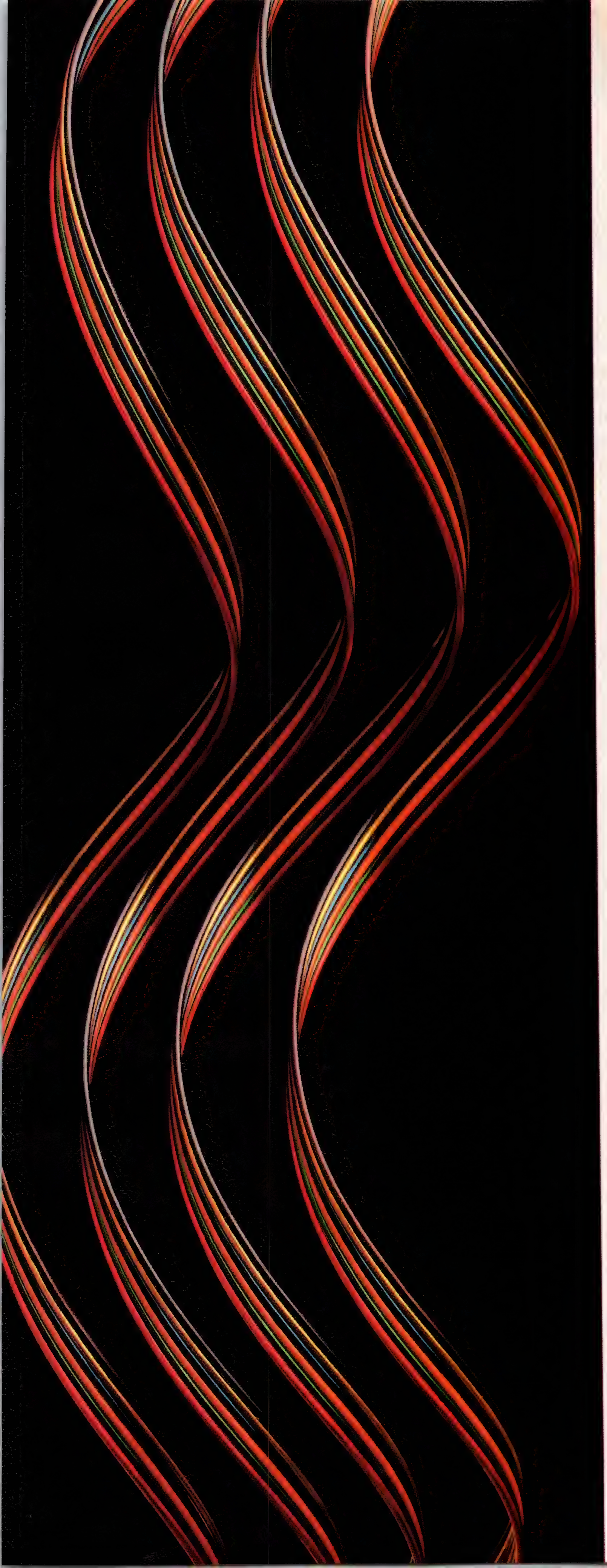
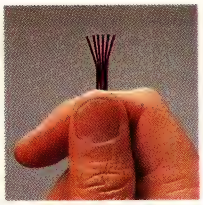

–12V
560
1/2 W
560
1/2 W
L2
L1
INPUT
SRD2
5082-0180
HP2811
OUTPUT
5082-0180
SRD1
L3
36 1/8 W
RLOAD
NOTES:
L1 = 3 TURNS, 1/4-IN. DIAMETER WIRE-WRAP WIRE
L2 = 1 TURN, 1/8-IN. DIAMETER DIODE LEAD
L3 = 7 TURNS, 1/4-IN. DIAMETER WIRE-WRAP WIRE
= FERRITE BEAD (AMIDON #63)
(a)
100mV
5nS
100mV
1nS
HORIZONTAL
10V/DIV
(b)
HORIZONTAL
10V/DIV
(c)

***Fig 1—By taking advantage of the switching nature** of step-recovery diodes, the circuit in **(a)** generates 1-nsec pulses **(b)** from a wider pulse input **(c)**.*





MULTIFILAR®

MAGNET WIRE

Parallel bonded for windings and leads.

When two or more magnet wires travel together, MULTIFILAR magnet wire is an excellent alternative.

This parallel bonded, color-coded magnet wire offers more consistent capacitance and impedance characteristics when compared to windings using two or more separate magnet wires.

And, it allows for increased layer winding speeds, as well as reduced labor and handling. Color-coding assists in conductor identification and helps eliminate termination errors.

MULTIFILAR magnet wire is custom produced to guarantee flat, parallel construction in an array of sizes, 16–52 AWG, with up to 20 conductors in some sizes.

Available constructions include round, flat or square conductors. Individual conductors meet NEMA MW 1000, JW 1177, temperature classes 105–220°C; single through quadruple film builds. Color-coded conductors are available in most insulations with up to 10 different colors in some sizes.

Call or write for your free copy of our Technical Data Booklet and Capabilities Brochure. Both contain valuable information on all wire produced and inventoried by MWS Wire Industries. Samples of MULTIFILAR are available upon request.

MWS

Wire Industries

31200 Cedar Valley Drive, Westlake Village, CA 91362
CALL TOLL FREE 800 423-5097
In California 800 992-8553. In L.A., 818 991-8553

MULTIFILAR® is a registered trademark of MWS Wire Industries

CIRCLE NO. 86

Inductor L_1 lets the slow input pulse pass but keeps the high-speed output pulse from coupling back into the input. Inductors L_2 and L_3 keep the output pulse from coupling into the power and ground paths, respectively. Using wire-wound inductors and ferrite beads minimizes the inductors' shunt capacitance. When calculating the actual rise and fall times as well as the amplitude of the output pulse, you need to account for the bandwidth of the scope you're using. After taking into account the response of the Tektronix 7104 scope with a 1-GHz plug-in, you'll find that **Fig 1b**'s pulse has a rise and fall time of 350 psec, an amplitude of 40V, and a width of 750 psec at half of the pulse's maximum amplitude, or 20V. The practical repetition rate is approximately 5 kHz if you use **Fig 2**'s driver circuit.

You can modify the amplitude of the output pulse if you adjust the diodes' dc bias by adjusting the values of the 36 and 560Ω resistors. The dc bias through the diodes and the input pulse's shape determine the switch point of the diodes. You can control the width of the output pulse by controlling the dc current through SRD_2. **EDN**

To Vote For This Design, Circle No. 747

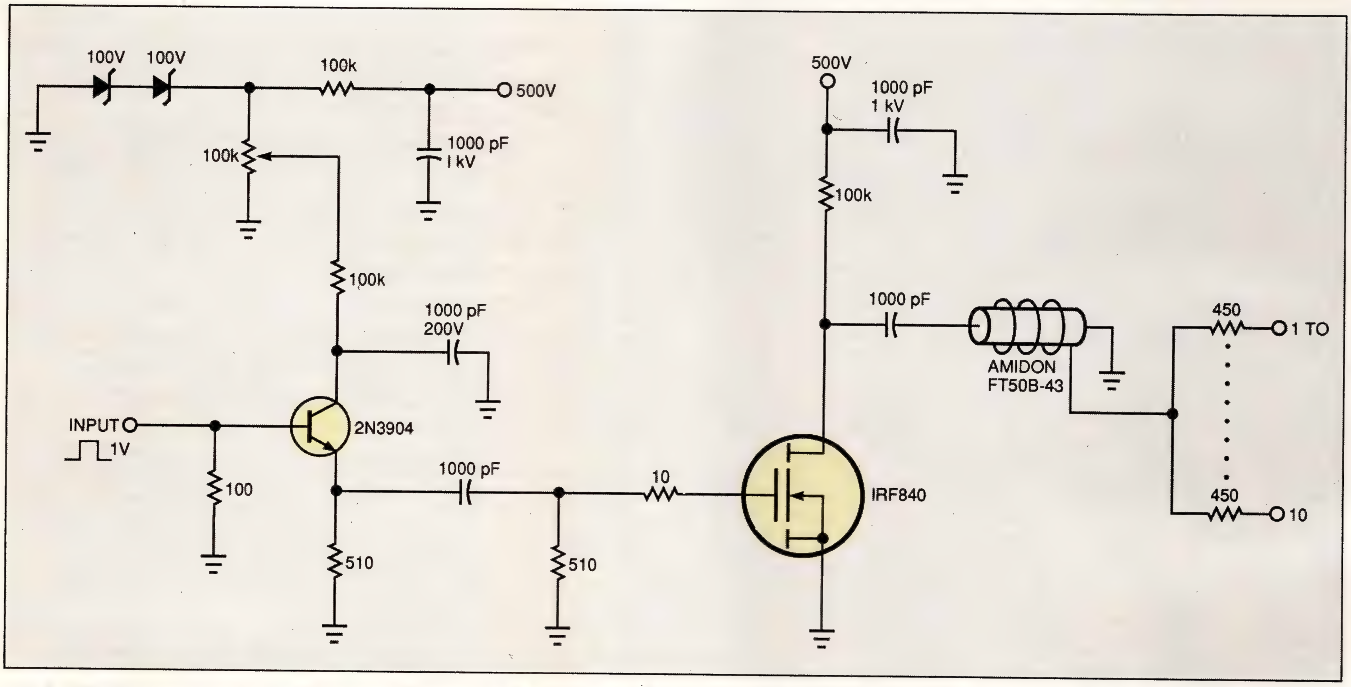


*Fig 2—**The characteristics of this input driver** and the dc bias of the step-recovery diodes determine the diodes' switching points.*

Software debounces µP inputs

Kevin Towers
Durand-Raute Industries Ltd, New Westminster, British Columbia, Canada

Listing 1's 68000-family assembly code debounces microcomputer inputs. The algorithm works well as an interrupt routine because the I/O processing doesn't complicate the structure of a controller's main task. How often the main program calls the subroutine sets the debounce time period, which is typically 30 to 40 msec. The program uses two static variables: last_in, which is a copy of the last input byte or word, and iports, which is the debounced input mask the foreground routines use.

The algorithm first inputs the data from the hardware device. Then, the algorithm tests to see which

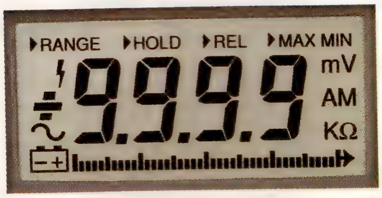
It's no fluke.

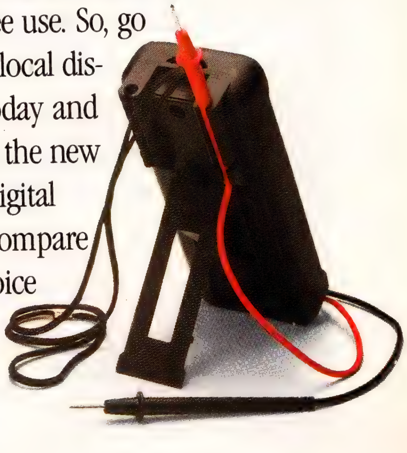
Made in the U.S.A.

Feature	Fluke Model 77	Beckman Industrial RMS225
Digits	3-½ Digits	**4 Digits**
Resolution	3,200 Counts	**10,000 Counts**
Accuracy	0.3%	**0.25%**
Automatic Reading Hold	Touch Hold®	**Probe Hold™**
Analog Bar Graph	31 Segments	**41 Segments**
Battery Life	2,000 Hrs	**500 Hrs**
10A Range	✓ (Fused)	✓ **(Unfused)**
Protective Holster	✓	✓
3 Year Warranty	✓	✓
True RMS		✓
Auto Max Min™		✓
Relative Mode		✓
Self-Resetting Fuse		✓ **(40mA Input)**
Price	$159*	**$149**

® Touch Hold is a registered trademark of the John Fluke Mfg. Co., Inc. * 1990 Fluke and Philips Catalog

Your best auto-ranging multimeter for the money. It doesn't happen by accident. It takes expertise, painstaking R&D, and a solid commitment to provide you with the features you've asked for at a price you can afford. When you add it all up, the new Beckman Industrial RMS225 simply outperforms any meter in its class. And like all the other multimeters we've built over the years, it's designed for long lasting and trouble-free use. So, go visit your local distributor today and check out the new RMS225 digital multimeter. Once you compare it to the others, the choice will be obvious.


▸RANGE ▸HOLD ▸REL ▸MAX MIN
9.9.9.9
mV
AM
KΩ



Beckman Industrial™

An Affiliate of Emerson Electric Co.

Instrumentation Products Division
3883 Ruffin Road, San Diego, CA 92123-1898
(619) 495-3200 • FAX (619) 268-0172 • TLX 249031
Outside California 1-800-854-2708 Within California 1-800-227-9781

CIRCLE NO. 87

© 1990 Beckman Industrial Corporation. Specifications subject to change without notice. Fluke is a registered trademark of John Fluke Mfg. Co., Inc.

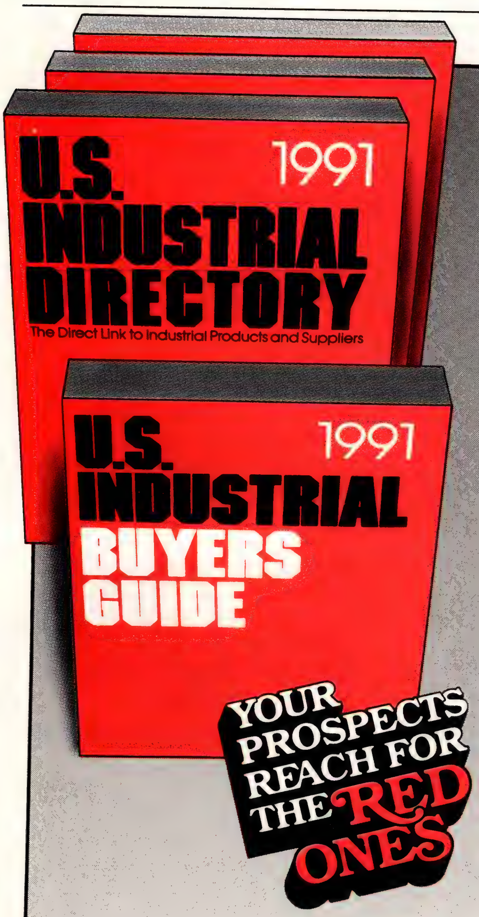
JN189-12-051090

bits changed since the last time the routine executed. The algorithm considers those bits that have changed to be unstable; therefore, it restores these bits to their previous values. The algorithm considers bits that have not changed since the last input to be stable and copies them into the debounced input mask. EDN

To Vote For This Design, Circle No. 748

Listing 1—Debouncing algorithm

```
        rd_inputs:
; read 4  8-bit hardware ports into a single long word
                move.b   inport_0,d1     ; read switches from hardware port
                lsl.l    #8,d1           ; move switches into upper byte
                move.b   inport_1,d1     ; read switches from hardware port
                lsl.l    #8,d1           ; move switches into upper byte
                move.b   inport_2,d1     ; read switches from hardware port
                lsl.l    #8,d1           ; move switches into upper byte
                move.b   inport_3,d1     ; read switches from hardware port

; the next line can be omitted for positive logic inputs systems
                not.l    d1              ; negative logic inputs

                move.l   last_in,d0      ; get the previous state of word port

                eor.l    d1,d0           ; find bits that have changed
                move.l   d0,d2           ; duplicate
                and.l    iports,d0       ; for bits which changed, save old bits
                not.l    d2              ; bits that have NOT changed
                and.l    d1,d2           ; map in reliable bits from harware
                or.l     d0,d2           ; map in bits from previous image
                move.l   d2,iports       ; save debounced image word
                move.l   d1,last_in      ; save the port word verbatim in last
                rts                      ; all done
```


U.S. 1991 INDUSTRIAL DIRECTORY
The Direct Link to Industrial Products and Suppliers
U.S. 1991 INDUSTRIAL BUYERS GUIDE
YOUR PROSPECTS REACH FOR THE RED ONES

DOUBLE YOUR SELLING OPPORTUNITIES

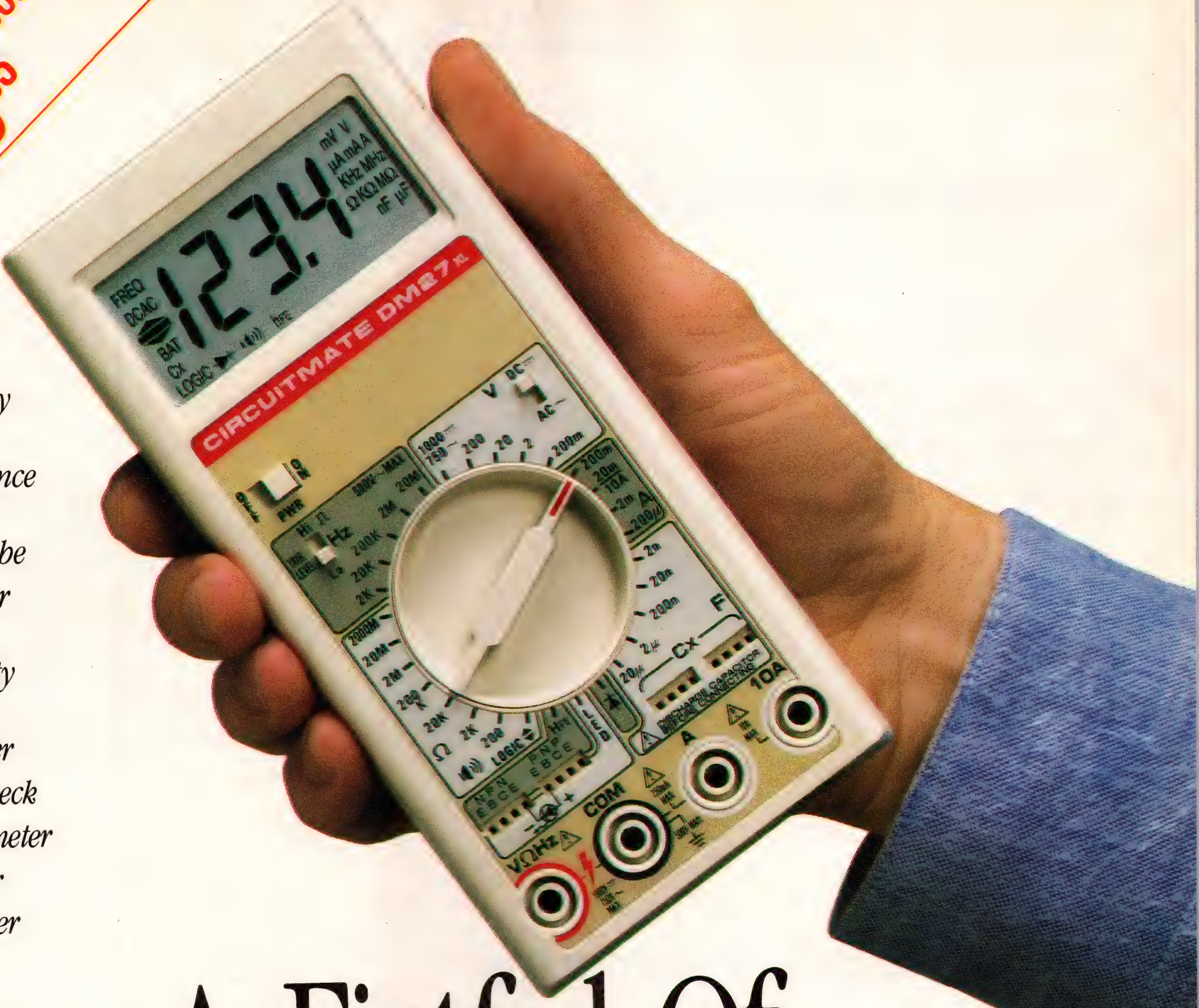
The U.S. INDUSTRIAL DIRECTORY and The U.S. INDUSTRIAL BUYERS GUIDE now reach twice as many key buyers in U.S. manufacturing as before. Total circulation for the 1991 edition is over 100,000, with heaviest coverage in Fortune 500 companies!

Advertise in U.S.I.D. and you automatically extend your reach with the new, extra volume—U.S. INDUSTRIAL BUYERS GUIDE. 50,000 additional circulation—over 100,000 in all. At no additional cost your efficiency is better than ever!

Call or write for more information on your many advertising options. The DIRECTORY and the BUYERS GUIDE make sales contacts for you year-round!

U.S. INDUSTRIAL DIRECTORY & BUYERS GUIDE
Reed International • Cahners Publications
8 Stamford Forum, P.O. Box 10277, Stamford, CT 06904 (203) 328-2500 FAX (203) 357-7864

ULL FEATURES FOR JUST \$129^{95}



- ☐ 20MHz Frequency Counter
- ☐ Capacitance Meter
- ☐ Logic Probe
- ☐ Transistor Tester
- ☐ Continuity Tester
- ☐ LED Tester
- ☐ Diode Check
- ☐ 10A Ammeter
- ☐ Voltmeter
- ☐ Ohmmeter

A Fistful Of Functions.

With more uses and features than most other hand-held multimeters, the DM27XL and DM25XL really pack a punch; especially when you've got to troubleshoot or analyze a variety of components and circuits.

Standard functions include capacitance measurement to 20μf, logic probe to 20MHz, transistor tester and resistance ranges to 2000MΩ. The DM27XL further adds 20MHz frequency counting capability with selectable trigger sensitivity, plus an LED tester. Both meters feature an enhanced display, including a large, easy-to-read LCD, a full set of function annunciators and a battery-saving Auto Power Off.

Grab a DM25XL for just $109.95, or a DM27XL for just $129.95 (suggested retail price) at your local Beckman Industrial distributor. After using one, you won't be able to function without it.

Beckman Industrial™
An Affiliate of Emerson Electric Co.

Instrumentation Products Division
3883 Ruffin Road, San Diego, CA 92123-1898
(619) 495-3200 • FAX (619) 268-0172 • TLX 249031
Outside California 1-800-854-2708 Within California 1-800-227-9781

CIRCLE NO. 88

© 1990 Beckman Industrial Corporation All specifications subject to change without notice.
JN193-12-051090

Calculators find resistor values

Nevitt Reesor
Woodward Governor Co, Fort Collins, CO

The calculator program in **Listing 1** takes a real number and returns the nearest standard resistor value. The program runs on Hewlett-Packard calculators such as the models HP28 and HP48; the formula comes from MIL-R-55182. **EDN**

To Vote For This Design, Circle No. 749

Listing 1—Floating-point conversion calculator routines

```
<<
    '10^(1/96)' → x y            ; Initialize the local variables.
    'y^IP(LN(x)/LN(y)+.5)'       ; Set up the conversion fomula.
    EVAL                         ; Evaluate the formula.
    2 ENG RND                    ; Round the result to three significant figures.
    4 FIX                        ; Reset the display format.
>>
```

C routine sets bit groups

Kamran Husain
R-Tel Systems, Bedford, TX

The C routine in **Listing 1** sets a selectable number of contiguous bits in an n-byte bit field. Bit 0 is the lowest-order bit in the first byte of the n-byte bit field. The bit-set routine suits memory-mapped hardware.

As the ANSI C "function prototype" at the head of the **listing** indicates, your calling program passes this routine three parameters: a pointer to the first byte of the n-byte bit field and the bit numbers of the first and last of the contiguous bits to be set. **EDN**

To Vote For This Design, Circle No. 750

Listing 1—Bit-setting C routine

```
set_bits_in_array(start_number, stop_number, a_ptr)
int start_number;
int stop_number;
char *a_ptr;
/*
    Author: Kamran B Husain
    Date:   Aug 29, 1988
    Function:
        This function sets the bits in an array of bytes (chars)

        The array is referenced by the pointer a_ptr and is
    indexed from 0 up. Bit 0 in the first byte is the right most
    bit, and bit 7 is the leftmost bit in the first byte.
*---------------------------------------------------------------*/
```

Listing 1—Bit-setting C routine *(continued)*

```
{
char start_byte;        /* 0 relative */
char stop_byte;         /* 0 relative */
char start_bit;         /* 0 relative */
char stop_bit;          /* 0 relative */
char start_mask;        /* 0 relative */
char stop_mask;         /* 0 relative */
int i;

/* ------------------------------------- */
/* Get the byte numbers by dividing by 8 */
/* ------------------------------------- */
start_byte = start_number >> 3;
stop_byte = stop_number >> 3;

/* ------------------------------------- */
/* Get the start and stop bit numbers    */
/* ------------------------------------- */
start_bit = start_number % 8;
stop_bit  = stop_number  % 8;

/* ------------------------------------- */
/* Generate masks for the start and stop */
/* bytes.                                */
/* ------------------------------------- */
start_mask = 0xff << start_bit;
stop_mask  = 0xff >> (7 - stop_bit);

/* ------------------------------------- */
/* Special Case, when only one byte has  */
/* to be modified.                       */
/* ------------------------------------- */
if ( start_byte == stop_byte )
   {
   start_mask = (0xff >> (7 - stop_bit)) & 0xf0;
   stop_mask =  (0xff << start_bit) & 0x0f;
   *(a_ptr+start_byte)|= start_mask + stop_mask;
   return;
   }
/* ------------------------------------- */
/* Set the intermediate bits             */
/* ------------------------------------- */
for ( i = start_byte;  i < stop_byte; i++)
   *(a_ptr + i) = 0xff;
*(a_ptr + start_byte)|= start_mask;
*(a_ptr + stop_byte )|= stop_mask;
}

/* LISTING 2 - Setting many Bits */
/* clear the array */
for ( stop = 0 ; stop < 100 ; stop++)
   array[stop] =0x00;
/* Set the bits */
   set_bits_in_array(0, 16, array);
   set_bits_in_array(31, 47, array);
```

Design Entry Blank

$100 Cash Award for all entries selected by editors. An additional $100 Cash Award for the winning design of each issue, determined by vote of readers. Additional $1500 Cash Award for annual Grand Prize Design, selected among biweekly winners by vote of editors.

To: Design Ideas Editor, EDN Magazine
Cahners Publishing Co
275 Washington St, Newton, MA 02158

I hereby submit my Design Ideas entry.

Name
Title Phone
Company
Division (if any)
Street
City State
Country Zip
Design Title
Home Address

Social Security Number
(Must accompany all Design Ideas submitted by US authors)

Entry blank must accompany all entries. Design entered must be submitted exclusively to EDN, must not be patented, and must have no patent pending. Design must be original with author(s), must not have been previously published (limited-distribution house organs excepted), and must have been constructed and tested.

Exclusive publishing rights remain with Cahners Publishing Co unless entry is returned to author or editor gives written permission for publication elsewhere.

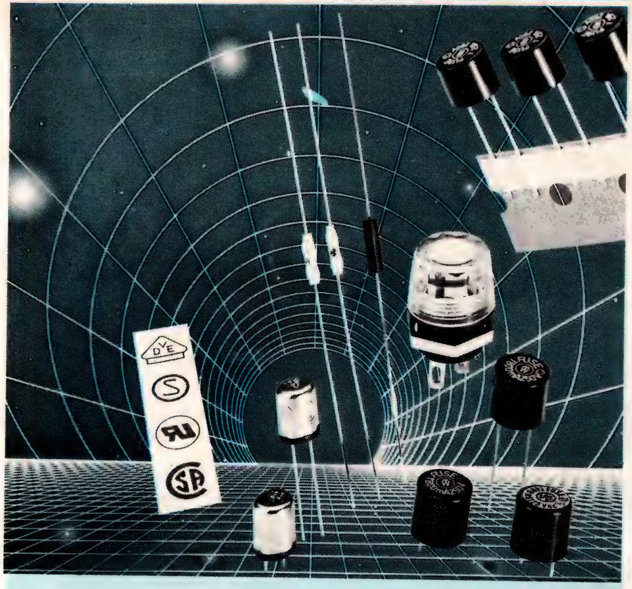
In submitting my entry, I agree to abide by the rules of the Design Ideas Program.

Signed
Date

ISSUE WINNER

The winning Design Idea for the February 1, 1990, issue is entitled "Averaging increases μP's ADC resolution," submitted by Tuomas Koljonen and Jarkko Vuori of Data-Guider OY Inc (Espoo, Finland).

Your vote determines this issue's winner. All designs published win $100 cash. All issue winners receive an additional $100 and become eligible for the annual $1500 Grand Prize. **Vote now**, by circling the appropriate number on the reader inquiry card.



A »multi-dimensional« programme

New dimensions in miniature fuses: Wickmann offers a wide range of internationally recognized and field proven sub-miniature fuses. For example Pico, Nano, Microfuse, TR 3 and TR 5 also available taped for automatic assembly methods. New: shock safe fuseholders for TR 5 for front panel mounting and p.c.b. fitting. What more could you want? Catalogue reference G 2 for more information.

A mark of safety

Wickmann-Werke GmbH

Postbox 2520 · D-5810 Witten 6 · Tel. 02302/6620 · Fax 02302/662219

CIRCLE NO. 13

Be An Author!

When you write for EDN, you earn professional recognition. And you earn $75 per published magazine page.

EDN publishes how-to design application information that is read by more than 137,300 electronics engineers and engineering managers worldwide. That's an audience that could belong to you.

If you have an appropriate article idea, send your proposal and outline to: EDN,
275 Washington Street, Newton, MA 02158-1630.

For a FREE EDN Writer's Guide—which includes tips on how to write for EDN and other technical publications—please circle number 800 on the Information Retrieval Service Card.

EDN

First in Readership among Design Engineers and Engineering Managers in Electronics.

How To Win The Real-Time Clock Game

Developing software for real-time applications can be a challenging game.

Dealing with a separate compiler, assembler, linker, loader, executive and debugger, each with its own procedures, can really slow you down. Just think of all the time you spend accessing files and conversing with all those tools, plus the time waiting for them to run.

There's a better solution—polyFORTH® It's a complete, fully integrated, interactive programming environment that's designed specifically for real-time applications. It supports single-chip microprocessors, 16- and 32-bit processors, DSP processors, and minis like the VAX.

The editor, compiler, assembler and debugger are always resident and ready to use. There's only one program to learn and no separate procedures to bog you down. You can move directly from thinking and editing to testing, with no distractions. It's an integrated approach that can dramatically improve your productivity and creativity.

Fact is, polyFORTH is far and away the most consistent, effective way to go from "design" to "done". Whether you do it yourself or have us design a turnkey system for you, expect to finish your real-time embedded applications 4 to 10 times faster than ever before.

After all, isn't that the name of the game?

Call 1-800-55-FORTH today for your free-for-the-asking "Real-Time Clock Game" poster and brochure with real-life programming solutions from FORTH.

FORTH, Inc., 111 N. Sepulveda Blvd., Manhattan Beach, CA 90266, 1-800-55-FORTH, (213) 372-8493

VAX is a trademark of Digital Equipment Corporation polyFORTH is a trademark of FORTH, Inc.

FORTH, Inc.

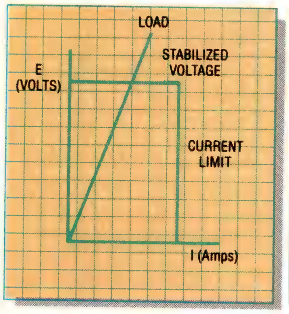
Circle 34, please send me more information

Circle 35, please have a salesman call me

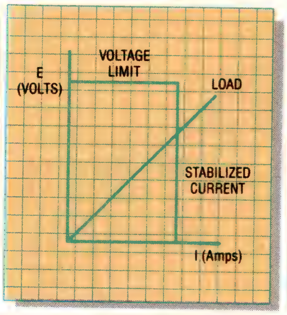
Multi Roles. One actor, many faces...

One power supply, many applications.

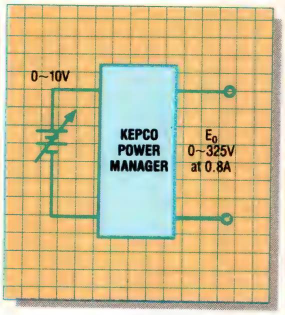
KEPCO'S SERIES ATE VOLTAGE STABILIZERS HAVE MANY ROLES...



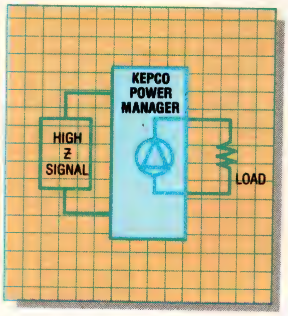
....SUPPLY STABILIZED VOLTAGE
0.001% voltage stabilizer



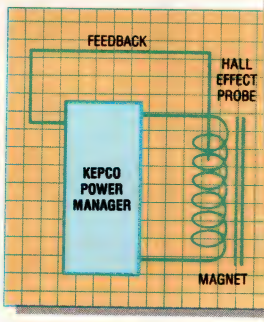
AND CURRENT.
0.005% current stabilizer



THEY'RE PROGRAMMABLE IN VOLTAGE MODE.
A voltage stabilizer controlled by a 0-10V d-c signal



THEY'RE PROGRAMMABLE IN CURRENT MODE.
A current stabilizer controlled by a high impedance source



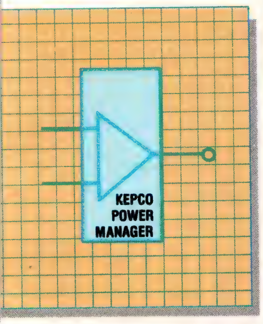
THEY'LL ACCEPT FEEDBACK.
A magnetic field stabilizer controlled by a Hall-effect senso

Model ATE 325-0.8M

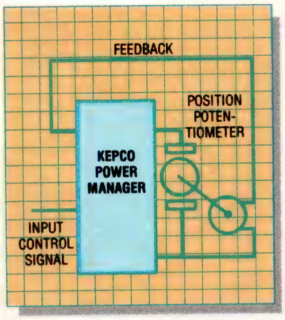
The actor/model is *Jan Leighton*, whose face has been photographed as everyone from Patton to MacArthur to Lincoln. One face, many roles. More than 3,372 historical notables according to his fact sheet!

The power supply is Kepco's ATE. While it cannot claim quite so many roles as Jan Leighton, its flexibility will delight you. ATE power supplies are comfortable in roles as voltage sources, current stabilizers, power amplifiers, GPIB listeners and MATE-verified talker-listeners.

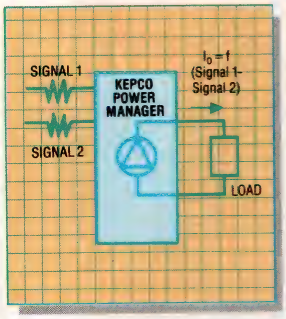
ATE are comfortable on your bench, in your systems or installed in your test rack . . . you can control them with analog signals or digital. You can use their integral uncommitted op amps to scale, sum, integrate or multiply a variety of signal stimuli in servo roles. A versatile piece of test equipment indeed.



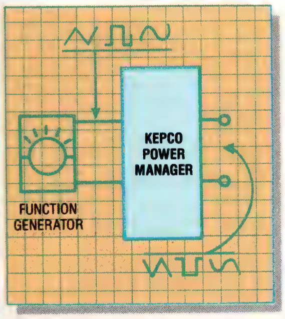
THEY'LL FUNCTION AS AN AMPLIFIER...
A self-powered oversized op-amp



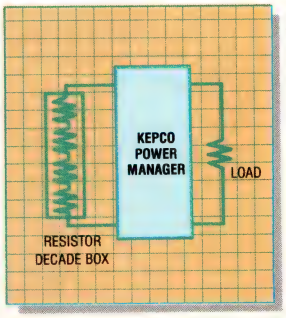
OR CONTROL A MACHINE.
A servo amplifier to drive a positioning motor



ATE CAN SUM INPUT CONTROL SIGNALS
A current stabilizer controlled by the difference between two signals



...BE DRIVEN BY AN ANALOG FUNCTION
A voltage stabilizer controlled by a signal generator



OR INTERFACE TO THE DIGITAL WORLD
A voltage stabilizer controlled by a passive resistance decade box

ATE are made in 5 power ranges, 50 to 1000W (voltage ranges 0-6V to 0-325V) to afford:

☐ High stability (less than 0.0005% source effect, 0.001% load effect).

☐ Very low ripple and noise (0.1mV rms, 1mV pp).

☐ Rapid recovery (<50μsec).

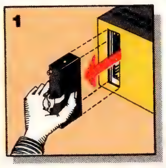
Most important... ATE's linear design supports a fast-programming mode which — for your control signals — allows a wide bandwidth response ... 16KHz in our 0-6V, 100 Ampere model, allowing roles ordinary power supplies cannot imagine.

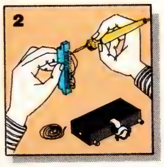
☐ *Fast Recovery* current stabilizer

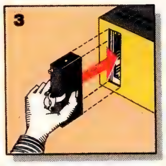
☐ *Wide band* power amplifier

☐ *Rapid response* to sequenced programs

Like Jan Leighton, Kepco's 41 different ATE models are capable of many roles, limited mainly by your imagination. We'd like to tell you more. Please write or call and request Kepco's new 1990 edition Catalog and Handbook (146-1678).

1


2


3


ATE's unique user port allows you access to the principal control points. A simple 3-step procedure allows you to configure your ATE for whatever role you require.

By appropriate wiring of the mating plug, your ATE easily assumes a variety of roles: voltage/current controller, resistance programmed, voltage programmed, digitally programmed, power amplifier, servo amplifier, integrator.

SEE US AT ELECTRO/90 KEPCO BOOTH 3406, 3408.

For your free copy of Kepco's new 120-page Linear Power Supply Catalog (#146-1678), call/fax/write to Dept. LLT-12,
Kepco, Inc., 131-38 Sanford Avenue, Flushing, NY 11352 USA • (718) 461-7000 • FAX (718) 767-1102 • Easylink (TWX): 710-582-2631

KEPCO
THE POWER SUPPLIER™

CIRCLE NO. 89

Commitment to Technology

Magazine Edition

The electronics industry's
leading design publication

▼

News Edition

The electronics industry's
only technical newspaper

▼

ELECTRONIC TECHNOLOGY FOR ENGINEERS AND ENGINEERING MANAGERS
A CAHNERS PUBLICATION

EDN

Multibus II
computer-board directory
Avoid digital-scope
aliasing errors
Data-compression devices
Brushless dc motors
Buscon/88 East preview

Analog-I/O cards
transform PCs into
data-acquisition systems

A CAHNERS PUBLICATION

Low-end fault tolerance
New realms for personal
computers and workstations 5

Portable oscilloscopes
The focus is on ease of use 8

LCD breakthrough
Material extends use of liquid
crystals 14

EDN
NEWS EDITION

Special Supplement:
Test and measurement—
ATE Market and technology
pullout section begins after
page 54

Career News
The shortage of microwave engineers continues 88

News of Products, Technology, and Careers for Engineers and Engineering Managers

BRIEFINGS

Modules yield denser systems

Preassembled subsystems, connectors, and motherboards save space

WILL DAVIES

IC makers grapple with metastability

A call for Ada experts

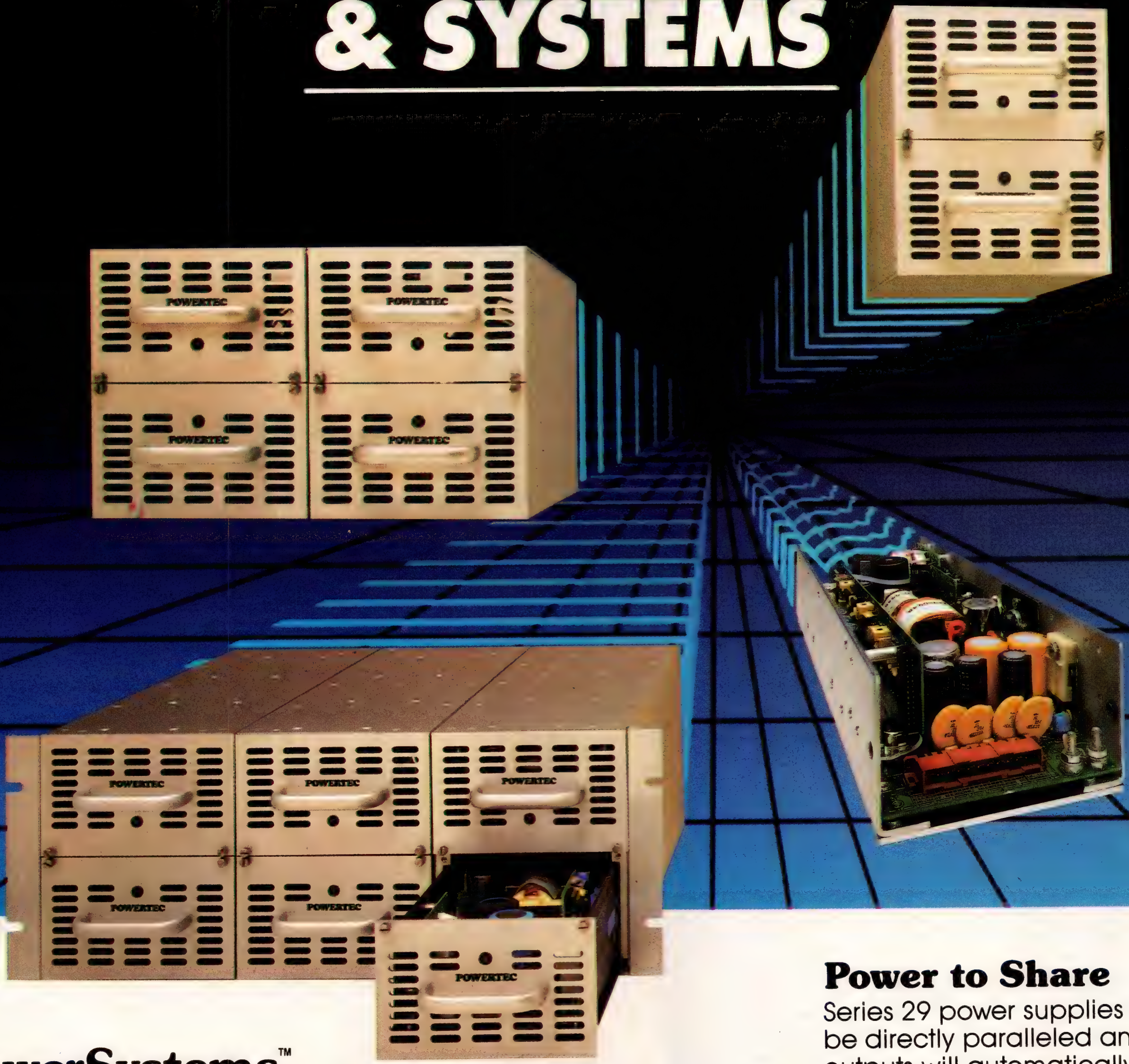
Although Ada's popularity is growing slowly, the demand for experts exceeds the supply

MICHAEL BALL
Contributing Editor

EDN
Magazine
Edition
News
Edition

A Partnership in Power and Prestige Worldwide

HOT PLUG-IN FAULT TOLERANT (N+1) POWER SUPPLIES & SYSTEMS



PowerSystems™ Series29

- N+1 Redundancy
- 5 to 15 Outputs
- Hot Plug-In/Replacement
- Automatic Current Sharing
- Expandable to 1800 Watts
- Zero System Down Time
- 5 to 24 VDC

Designed for Reliability

Powertec's Series 29 power supplies are designed to specifically meet fault-tolerant/redundant-mode requirements for communications, process control, and computer system applications.

Power to Share

Series 29 power supplies can be directly paralleled and the outputs will automatically load share. In addition, individual outputs with equivalent voltages paralleled with each other will current-share proportional to their current ratings.

All models have five isolated, floating outputs from 5 to 24 VDC. Each output has remote sense, output good, and inhibit signals.

POWERTEC
A DIVISION OF ASTEC AMERICA, INC.
ASTEC

401 Jones Road, Oceanside, CA 92054-1216
Tel: (619) 439-4200 Fax: (619) 439-4243

See us at Electro 90, Hynes Convention Center, Booth 1735

CIRCLE NO. 91

"WE DEPEND ON ***EDN'S MAGAZINE*** AND ***NEWS EDITIONS*** TO DELIVER THE SPECIFICS ON MAXIM PRODUCTS TO POTENTIAL CUSTOMERS."

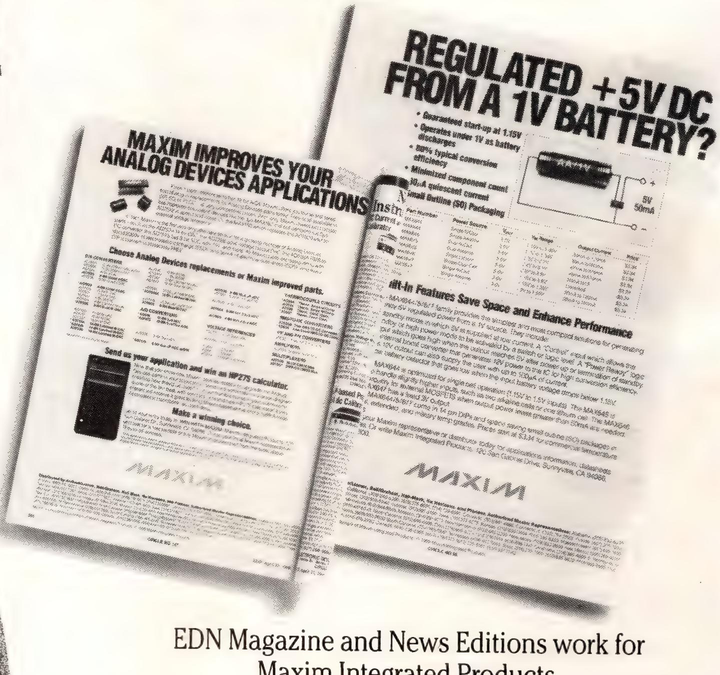
Mike Dikas
Director of Communications
Maxim Integrated Products

Maxim Integrated Products is one of today's fastest growing international suppliers of quality analog ICs. In the past five years they have introduced more than two hundred proprietary and improved second source devices.

Director of Communications, Mike Dikas has piloted Maxim's advertising program since its inception. "EDN's magazine and news editions have played a significant role in introducing many of our new products. In the past two years, over 25,000 EDN Magazine and News Edition readers have responded to Maxim ads, product releases and articles," says Mike. "Our ads consistently fall in the top 10% in reader response in both editions of EDN. What's even more amazing is that we typically get less than 5% duplication of responses to the same ad in both the Magazine and News Editions."

What's that mean for Maxim? "Since both editions deliver the same circulation, it's apparent to us that the same engineers read both the Magazine and News Editions for different reasons. Given Maxim's charter of product proliferation, EDN's in-depth coverage of technical issues and timely coverage of new products are both of the utmost importance to Maxim."

Mike Dikas believes in the complementary roles of EDN Magazine and EDN News Editions.



MAXIM IMPROVES YOUR ANALOG DEVICES APPLICATIONS

Choose Analog Devices replacements or Maxim improved parts.

Send us your application and win an HP27S calculator.

Make a winning choice.

MAXIM

REGULATED +5V DC FROM A 1V BATTERY?

- Guaranteed start-up at 1.15V
- Operates under 1V as battery discharges
- 80% typical conversion efficiency
- Minimized component count
- 10μA quiescent current
- Small Outline (SO) Packaging

ilt-In Features Save Space and Enhance Performance

MAXIM

EDN Magazine and News Editions work for
Maxim Integrated Products.
They can work for you.

EDN

A Partnership in Power and Prestige Worldwide.

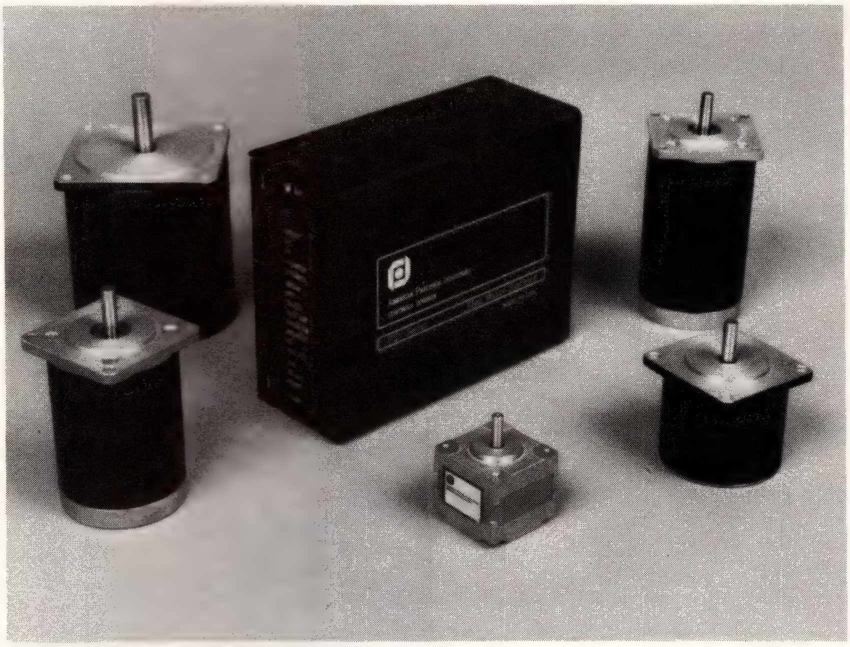
COMPONENTS & POWER SUPPLIES

Step Motor/Driver Packages

- *Operate from either 115 or 230V ac sources*
- *Offer half-step resolutions*

Housed in a package measuring just 2.5×5×6.75 in., P51 Series devices offer full- and half-step resolutions. Static torque figures range from 20 to 300 oz-in. All inputs are optically isolated and can be operated from 115 or 230V ac power sources. Each package comes complete with motor, drive, integral heat sink, cabling, and connectors. Users can specify control options to suit their own applications. Package containing a size 23 motor, $485.

American Precision Industries, 4401 Genesee St, Buffalo, NY 14225. Phone (716) 631-9800. FAX (716) 631-9368. **Circle No. 409**



Coaxial Connectors

- *Conform to DIN 41612*
- *Have a 1.2:1 VSWR*

The 45K line of coaxial connectors includes versions that conform to DIN 41612. Available for straight or right-angle pc-board-mounting applications, the units accept cables with diameters of 0.08 to 0.12 in. The connectors accommodate frequencies of 30 GHz and have a 50Ω characteristic impedance. At 10 GHz, the VSWR for a mated pair equals 1.2:1. £1.89 (100).

Rosenberger Micro-Coax Ltd, 1646 Parkway, Solent Business Park, Whiteley, Fareham PO15 7AH, UK. Phone (489) 886686. FAX (489) 886670. **Circle No. 410**

Solid-State Relays

- *Rated to 90A*
- *Have a 1200V blocking rating*

These solid-state relays feature 75 and 90A ratings at 280V ac and 50, 75, and 90A ratings at 480V ac. Each is available with 3 to 32V dc, 18 to 36V ac, or 90 to 280V ac inputs. Both zero ac and random turn-on versions are also available. Blocking rating equals 600 and 1200V for 280 and 480V ac models, respectively. All units incorporate a dual SCR output and an RC snubber network and have a 4-kV isolation figure. These UL-recognized relays are housed in the industry-standard hockey-puck package. $45.50. Delivery, stock to eight weeks ARO.

Gordos, 1000 N Second St, Rogers, AR 72756. Phone (800) 643-3500. **Circle No. 411**

Socket Converter

- *Handles four microcontrollers*
- *Accepts an 84-pin emulator plug*

The 84-PGA/68PLCC-A low-profile socket converter facilitates the use of an in-circuit emulator for four different Siemens microcontrollers (using either CMOS or NMOS technologies) in the same pod. The pin-grid-array (PGA) to plastic-leaded-chip-carrier (PLCC) unit accepts an 84-pin PGA emulator plug normally used for the emulation of 80C517 and 80C537 microcontrollers and converts this pinout to a 68-pin PLCC plug, which is required for the emulation of 80C515 and 80C535 devices. A single jumper on the underside of the socket allows you to select for CMOS or NMOS processors. The unit accommodates frequent insertions without damaging the socket in the target system. $210.

EDI Corp, Box 366, Patterson, CA 95363. Phone (209) 892-3270. FAX (209) 892-3610. **Circle No. 412**

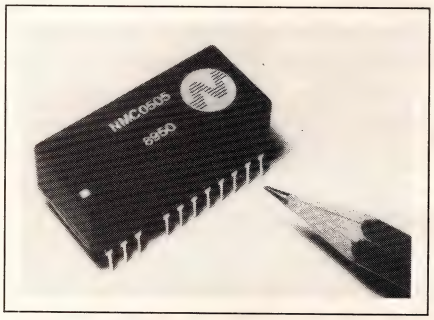
Extender/Test Adapter Boards

- *Available in 16- and 32-bit models*
- *Aimed at IBM architectures*

These extender/test adapter boards are designed for the IBM PS/2 architecture and PC/AT product lines. Offered in 16- and 32-bit models, the panels feature 4-layer microstrip construction, power and ground commitments that meet the Micro Channel and AT specs, and test points on all signal lines. Both the high-performance and standard extender boards come with mounting brackets, card guides with an ejector mechanism, and a connector with elongated leads suitable for scope-probe hookups. The high-performance models include features such as a power on/off switch, filter capacitor on the board side of the switch, and DIP switches for interrupting signal lines. $514 and $779 for standard and high-performance IBM PS/2 models, respectively; $589 and $725.25 for standard and high-performance IBM PC/AT versions, respectively.

Augat Interconnection Products Group, 33 Perry Ave, Attleboro, MA 02703. Phone (508) 222-2202. FAX (508) 222-0693.

Circle No. 413



DC/DC Converters

- *Feature dual-polarity outputs*
- *Housed in 24-pin DIPs*

NMC Series dc/dc converters accept 5 or 12V inputs and develop outputs of ±5, ±9, ±12, or ±15V. The converters are rated for 2W, and their efficiency equals 80%. Isolation measures 500V. You can select converters that have outputs regulated to 1% or units that have unregulated outputs. Both versions are housed in 24-pin DIPs. $24 (100) for a model with a regulated ±5V output.

Newport Components Ltd, Tanners Dr, Blakelands N, Milton Keynes MK14 5NA, UK. Phone (908) 615232. FAX (908) 617545.

Circle No. 414

Photoelectric Sensor

- *Housed in a watertight case*
- *Features built-in protection circuitry*

The latest additions to the MF18 line of photoelectric sensors operate with any ac or dc control-voltage level between 24 and 240V. The devices are available in through-beam, retroreflective, and diffused-reflection models. All are housed in a noncorrosive watertight case for maximum environmental protection. The units feature a FET out-

Lattice Tools Fit Your Needs

Lattice ES C Development Systems Provide A Complete Set Of Tools:

- 100% ANSI C Compiler
- Global Optimizer
- Linker/Locator
- Macro Assembler
- Extensive C Library Functions
- Start-Up Routine Source Code
- Symbolic Debugger
- C Cross Reference Generator
- Disassembler
- Object Module Librarian
- Object Module Translator
- Make Utility
- File Handling Utilities
- Complete Documentation
- Numerous Files & Examples
- Free Technical Support

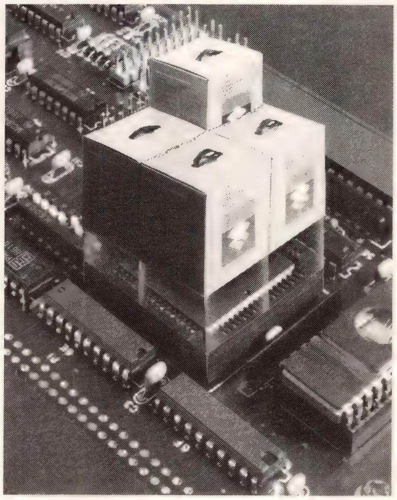
Host	Target	Price
DOS & OS/2	Motorola 680x0	900.00
Apollo	Motorola 680x0	2,000.00
DOS & OS/2	Intel 80x86	900.00
Apollo	Intel 80x86	2,000.00
DOS & OS/2	NEC 78310/12/12A	1,500.00
DOS & OS/2	NEC 7832x/7833x	2,200.00
DOS	Zilog Z80	500.00

Call or write for a free catalog.

Lattice

Lattice, Incorporated
2500 S. Highland Avenue
Lombard, IL 60148

Subsidiary of SAS Institute Inc.



Lattice ES C Compilers Are Made For ES Applications

Building embedded systems programs with tools made for PC applications is like trying to fit a round peg in a square hole. But Lattice ES C Development Systems are specifically designed for embedded systems programming.

Lattice ES C Compilers provide 100% ANSI compatibility plus language extensions, special keywords, and options that meet the specific needs of embedded systems programmers. Lattice also provides a global optimizer that increases your programs' speed up to 30%. Built-in functions and register variables enable you to minimize code size and maximize performance.

Order today and see the difference proper tools make!

Phone: 1-800/444/4309
708/916-1600
FAX: 708/916-1190
Telex: 532253

CIRCLE NO. 15

.99

MEETS IEC 555-2

Pioneer Can Deliver .99 Power Factor. NOW!

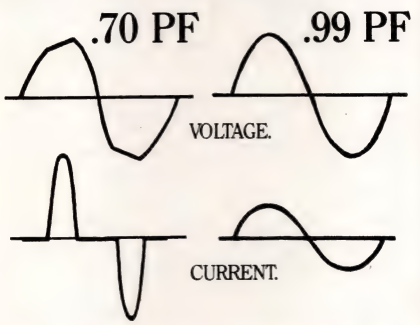
While others talk, Pioneer's customers are enjoying the benefits of power supplies with built-in .99 active PFC today.

In over 2400 voltage-current configurations, from 250 to 2000 watts, single or multiple output.

Pioneer can give you 1000 watts of DC power from a standard 115-V 15-A wall outlet and comply with UL's 12 A limitation. That's 300 more watts of usable power for system peripherals and accessories.

Plus, insensitivity to input voltage and frequency variations over a range of 90-264 VAC, DC-120 Hz eliminates strapping or switching.

You'll also get the added benefits of improved holdup performance, reduced line harmonics, less stress on system wiring, and decreased UPS size.



With .70 PF, current is drawn as narrow spikes during a short period of each half cycle. Power available from the line is cut by about 30%. In addition, harmonics generated by the excessive peak current produce substantial power line noise and distortion.

With .99 PF, line current and load current are in-phase, significantly raising available power and virtually eliminating harmonic distortion.

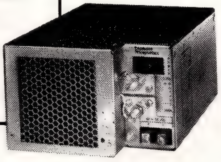
Because load current drawn from the line is a sine wave rather than a spike, conducted EMI filtering is simplified. In fact, these units meet the requirements of IEC 555-2 which limits third and higher harmonics. They also meet international safety standards, including UL1950, CSA 1402C and 220, IEC 380 and 435 and EN60950. All Pioneer standard and custom options are available.

Our 100% testing and 48-hour full-power burn-in ensures you of Hi-Rel, top quality supplies.

We've been building high-power switchers over 30 years and shipped over 350,000 worldwide.

So call us at 800-233-1745, or 800-848-1745 in CA. Or write to

1745 Berkeley St.,
Santa Monica, CA
90404.
Fax: 213-453-3929.



Pioneer Magnetics

CIRCLE NO. 93

put device that develops a 100-mA drive signal. A built-in output-protection circuit limits damage caused by incorrect wiring. $49 (100).

Aromat Corp, 629 Central Ave, New Providence, NJ 07974. Phone (800) 228-2350; in NJ, (201) 464-3550. FAX (201) 464-8513.

Circle No. 415

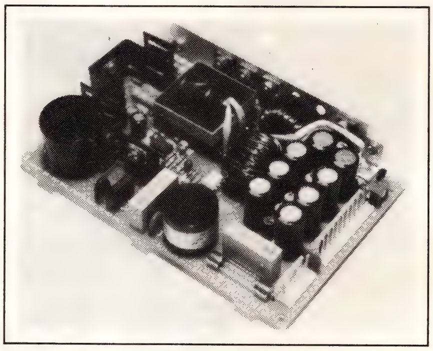
Quad-Output DC/DC Converters

- *Operate at 78% efficiency*
- *Provide 60W of power*

These quad-output dc/dc converters will supply ±5 and ±15V at power levels ranging to 60W continuous. Efficiency equals 78%. The converters come with 12 or 24V inputs. The 5V output is regulated to 1%; auxiliary outputs have a 3% load-regulation rating. Peak-to-peak ripple noise is guaranteed to be less than 50 mV on all outputs over the full −40 to +85°C operating range. The units are designed for 85°C baseplate operation, but they will accommodate occasional operation at 105°C. The converters are housed in an open aluminum chassis. $150 (1000) for a 12V-input model.

Custom Power Systems Inc, 33 Comac Loop, Ronkonkoma, NY 11779. Phone (516) 467-5328.

Circle No. 416



Power Supply

- *Features a universal input*
- *Has onboard EMI filtering*

The SRW-65 Series power supply provides four outputs in a compact 6×4×1.125-in. package. These 65W units accept any input between 85 and 264V ac without user intervention. Key parameters include a 50-mV p-p noise output, 1% total regulation for the main output, 20-msec holdup time, and a 0 to 50°C connection-cooled operating range. Submitted for testing to UL 1950, CSA22.2 No. 234-M, and EN60950 (TUV) international safety standards, the supply features an onboard EMI filter that meets FCC and VDE level B specifications. $98.

Integrated Power Designs Inc, 9C Princess Rd, Lawrenceville, NJ 08648. Phone (609) 896-2122.

Circle No. 417

Text continued on pg 176

Analog Design

Digital Design

EE Designer III™

offers superb design and simulation capabilities for both.

Total Integration assures smooth, error-free data transfer throughout the system with functionally organized menus to speed you through your design jobs.

No Limitation means that EE Designer can handle SMT, ground planes with heat-relief pads, thermal analysis, hybrid designs and more.

After 6 years of development and continued refinement, EE Designer has proven to over 14,000 users world-wide to be the one system that gets the job done.

Find out more about EE Designer, the choice of serious PCB design professionals by calling Visionics/Betronex or your local EE Designer Value Added Reseller.

In North America
Visionics Corporation
3032 Bunker Hill Lane
Suite 201
Santa Clara, CA 95054
Tel: 1-800-553-1177
Fax: (408) 492-1380

International
Betronex International
Enhagsslingan 19
Box 314
183 24 Taby, Sweden
Tel: (46) 8 792-2630
Fax: (46) 8 768-8794

CIRCLE NO. 16

LINEAR TECHNOLOGY
DESIGN NOTES

Number 34 in a series from Linear Technology Corporation *May, 1990*

Active Termination for SCSI-2 Bus

Sean Gold

Overview of SCSI-2

The SCSI-2 bus[1] is an interface for computers and instrumentation that communicate over small distances — often within the same cabinet. Like GPIB (IEEE 488), SCSI's hardware and software specifications are designed to coordinate independent resources such as disk and tape drives, file servers, printers, and other computers. SCSI-2 is a bidirectional bus, which must be terminated at both ends to 2.85V (Figure 1). The terminators are needed because SCSI-2 uses simple open collector output drivers in its transceivers. Terminators link communicating devices to the supplies, and roughly match the transmission line's characteristic impedance. When the load to the bus increases, the role of the termination network becomes more important for maintaining signal integrity at high data rates. An active termination design is now a part of the SCSI-2 standard and is presented here in-depth.

The single ended SCSI-2 bus is limited to six meters in length, and supports variable speed communication up to 5M transfers/sec. The bus nominally uses 18 data lines which defines the loading requirements for the terminators, because each output driver can sink at most 48mA. Up to eight SCSI devices can access the bus at regular distances along the cable. Any two devices can terminate the cable, but bit error rates are minimized with the terminators attached only at the ends. Local capacitive loading is low under these conditions, making the transmission line more consistent with fewer discontinuities.

SCSI-2's key specifications are repeated from the ANSI standard in Table 1.

Table 1. Single Ended SCSI-2

PARAMETER	VALUE	COMMENTS
Termination Supply	$4.25 < \text{TERMPWR} < 5.25$	0.9A Typical 1.5A Worst Case
Logic Supply	$V_{OUT} = 2.85V @ 0.5A$ $2.6 < V_{OUT} < 2.9$	Per Terminator
Data Rate	5M Transfers/Sec.	Six Meters Max.
Cable Impedance	110Ω $80 < Z_0 < 140$	Nominal
Transceivers	TTL Compatible	Negative True Logic 5V = 0, 0V = 1
Signal Levels	$0 < V_{OL} < 0.5$ $2.5 < V_{OH} < 5.25$ $V_{IL} < 0.8$ $2.0 < V_{IH}$ $0.2 < \text{Hysteresis}$	$-0.4mA < I_{IL} < 0mA$ $0.0mA < I_{IH} < 0.1mA$
Short Circuit Current	48mA/Transceiver	Based on Old TTL Spec

---

[1] **Note 1:** SCSI-2 = Small Computer System Interface Version 2, pronounced "Scuzy-2." The complete specifications standard is available through ANSI #X3T9.2.

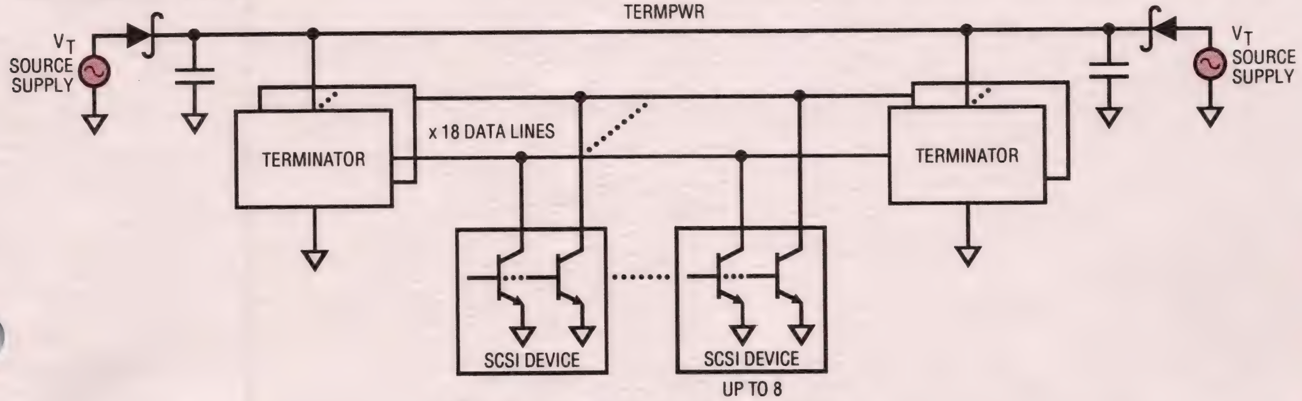


Figure 1. Global View of the SCSI-2 Bus

Shortcomings of Passive Terminators

The resistive voltage divider shown in Figure 2 is commonly used to terminate the SCSI bus. Multiple power sources are allowed to connect to the SCSI cable. Each source is protected with a Schottky diode to prevent damage from reverse currents. The resulting termination power signal, TERMPWR, is not well regulated — subject to variations in source supplies and protection diodes, as well as ohmic losses. Unfortunately, these changes in TERMPWR translate directly to the bus through the resistive divider, which degrades noise margins.

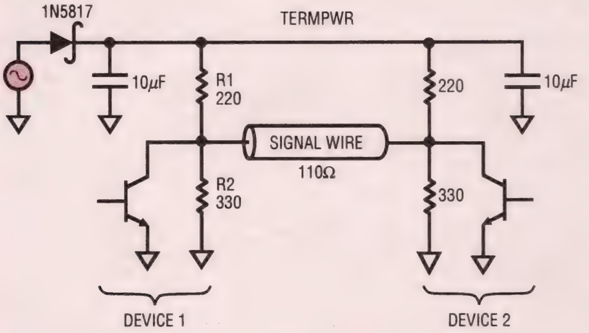


Figure 2. Passive Termination

The low values for R1 and R2 reflect a compromise between driver sink current and impedance matching the signal lines. Normally, high resistances would be desirable to minimize driver sink current. Yet, the terminator should match the signal line's 110Ω characteristic impedance, and the bus's quiescent state must be above the TTL logic threshold. It is not possible to meet all of these objectives simultaneously. The SCSI standard suggests R1 = 220Ω and R3 = 330Ω. The resulting bus voltage is 3V with 132Ω impedance, which is grossly mismatched to the nominal 110Ω cable impedance. The Schottky diode aggravates the mismatch because it presents a poor AC ground. In addition to these problems, the small resistors draw 300mA Q-current from TERMPWR, assuming 18 signal lines with the bus inactive.

Active Terminators

The active terminator shown in Figure 3 uses an LT1086 low dropout regulator to control the logic supply. The LT1086's line regulation makes the output immune to variations in TERMPWR. After accounting for resistor tolerances and variations in the LT1086's reference, the absolute variation in the 2.85V output is only 4 percent over temperature. When the regulator drops out at TERMPWR – 2.85V = 1.25V, the output linearly tracks the input with a slope of 1V/V. Signal quality is superior to the passive terminator because the 110Ω series resistor closely matches the transmission line's characteristic impedance, and the regulator provides a good AC ground.

In contrast to the passive circuit, two LT1086s require only 20mA quiescent current. For the power levels in this application, the LT1086 does not need a heat sink, and is available in low cost TO-220 or surface mount packages. Beyond solving basic signal conditioning problems, the LT1086 handles fault conditions with short circuit current limiting, thermal shutdown, and on-chip ESD protection circuitry.

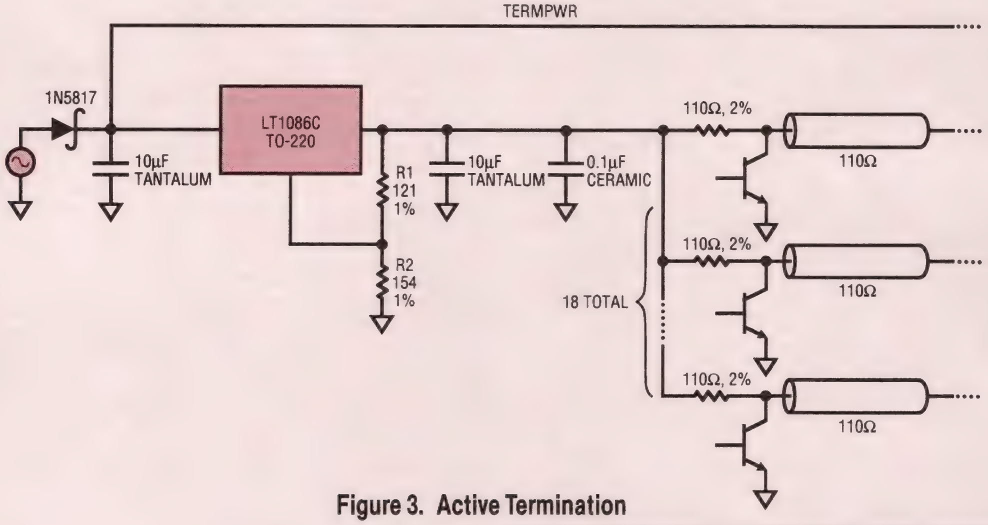


Figure 3. Active Termination

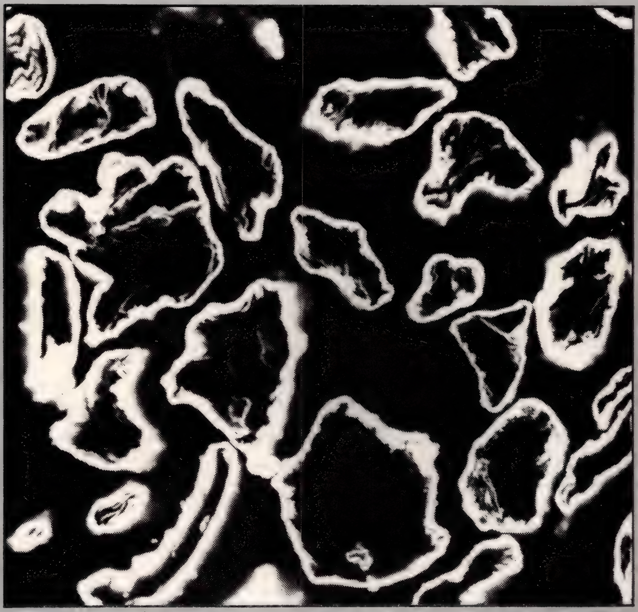
For literature on linear regulators, call **(800) 637-5545.**
For applications help, call (408) 432-1900, Ext. 209.

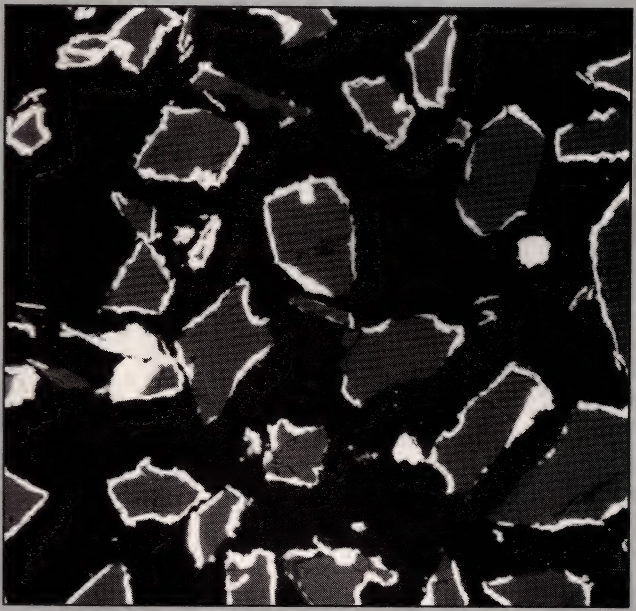
Linear Technology Corporation
1630 McCarthy Blvd., Milpitas, CA 95035-7487 • (408) 432-1900
FAX: (408) 434-0507 • TELEX: 499-3977

IM/GP 490 180K

© LINEAR TECHNOLOGY CORPORATION 1990

CHOOSE INCO COATED PRODUCTS FOR HIGH PURITY AND PREDICTABLE PROPERTIES.


Nickel Coated Graphite Powders


Nickel Coated Alumina

INCO Specialty Powder Products' development of the use of carbonyl gas coating allows deposition of nickel with very high purity and predictable properties and is uniquely suited for a variety of coated products and applications.

INCO SPP COATED PRODUCTS

Nickel combines a unique mixture of special physical, conducting and magnetic properties. The ability to deposit nickel on various substrates greatly extends the potential for the use of these properties. Coatings are being made, for example, on silica, graphite, alumina, tungsten carbide, clays and ceramics. INCO SPP has the capability to coat special substrates on a custom basis for individual users.

APPLICATIONS

New uses for INCO SPP Coated Products include conducting film technology, electronics packaging, EMI shielding, electronic detection devices, controlled heating systems, hard metals and powder metallurgy parts.

RESEARCH

INCO SPP research activities for this line of products include nickel carbonyl coated powders and other substrates. Applications include advanced products for EMI shielding, ESD, arc welding, powder metallurgy additives, and in battery technologies.

One highly interesting area of research is in the area of electronic detection. Coated products are being combined with paint for highway divider strips and as ink in bar codes for vehicle identification. This could provide an accurate measure of automobile speed on those highways. Another futuristic consideration is "computer trips for cars" using those strips and bar codes to program automotive travel and identification.

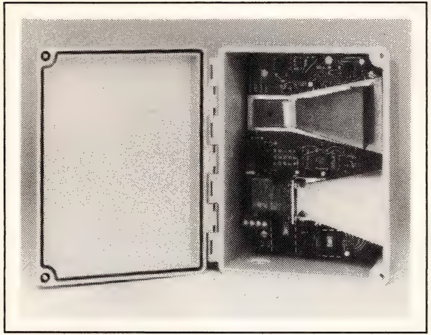
INCO SPP

INCO Specialty Powder Products is your unique resource for coated products. Our customer focused worldwide marketing service group is ready to help you with your current and future needs for coated products.

For more information write INCO Specialty Powder Products, Dept. 2-90, Park 80 West-Plaza Two, Saddle Brook, NJ 07662

INCO SPP

Park 80 West-Plaza Two, Saddle Brook, NJ 07662
Shin-Muromachi Building, 4-3 Nihonbashi-Muromachi 2-Chome, Chuo-ku, Tokyo 103 Japan
1-3 Grosvenor Place, London SW1X7EA England
15/Fl Wilson House, 19-27 Wyndham Street Central, Hong Kong



Noncontact Sensor

- *Has a 25-ft range*
- *Includes signal-conditioning circuitry*

The MSM20000 noncontact point-level/presence sensor determines if an object has come within a specified distance of the sensor. It also detects the presence or absence of moving and nonmoving objects within its detection pattern. The sensor has a sensing range of 25 ft max. Based on microwave technology, the unit accepts inputs of 15 to 40V dc and operates over a −40 to +85°C range. The signal-conditioning circuitry converts the detected output to a switch closure of 10A max at 277V ac or 24V dc. The unit also provides a separate optical-isolator output. The sensor is housed in a weather-tight 8.5×6.5×4.25-in., fiberglass enclosure, which meets NEMA 4, 4X, 12, and 13 ratings. $365.

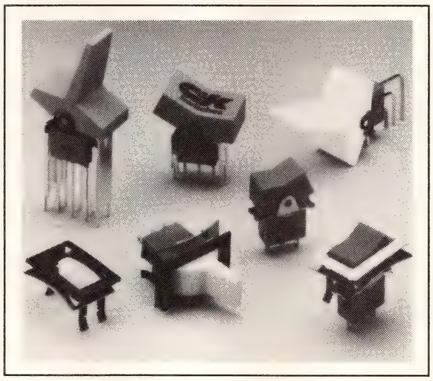
Alpha Industries, 20 Sylvan Rd, Woburn, MA 01801. Phone (617) 935-5150. FAX (617) 935-4939.
Circle No. 418

Tunnel-Diode Detector

- *Has 0.4-dB flatness*
- *Typical VSWR equals 1.7*

Model ACTP-1648 is a tunnel-diode detector that's structured as a 50Ω transmission line. The package features a type N input and a type BNC output that will accommodate laboratory and military system applications as well as power monitoring needs. The detector has a ±0.4-dB-frequency flatness over a 4- to 8-GHz range, a 700-mV/mV K-factor sensitivity, and a −50-dB tangential sensitivity. VSWR is typically 1.7. The detectors can be built to generate either a positive or negative output. The detector is housed in a hermetically sealed package to withstand severe environments and can be screened to MIL-STD-883. $165. Delivery, four to six weeks ARO.

Advanced Control Components, Box 4928, Clinton, NJ 08809. Phone (201)534-6155. FAX (201) 534-5625.
Circle No. 419

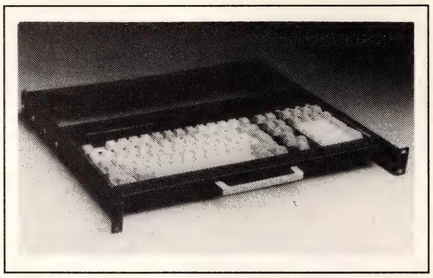


Sealed Switches

- *Designed to be process compatible*
- *Carry UL 94V-0 rating*

E Series sealed rocker- and lever-handle switches are designed to be fully process compatible to withstand soldering temperatures and cleaning solvents. Features include thermoplastic housing, which has a UL 94V-0 rating, an epoxy terminal seal, and an internal O-ring actuator seal. The line includes single-, double-, and triple-pole models and eight switching functions. Gold-plated contacts switch 7.5A max at 125V ac or 28V dc; silver contacts handle 3A at 250V ac. Electrical life measures 40,000 operations at full load. Insulation resistance and sea-level dielectric strength equal $10^9 \Omega$ and 1000V rms, respectively. Single-pole models, $2.84 (1000).

C&K Components Inc, 15 Riverdale Ave, Newton, MA 02158. Phone (617) 964-6400. FAX (617) 332-2379.
Circle No. 420



Industrial Keyboard

- *Designed for hostile environments*
- *Compatible with IBM PCs*

Compatible with the IBM PC, PC/XT, PC/AT, and PS/2, the R-19 full-travel keyboard is designed for hostile-environment applications. With an international-protection rating of 54, the unit is impervious to dust and liquid spills often found at industrial installations. The unit features molded silicone dome technology as well as sealed electronics. Special features include 12 function keys, 19-in. rack mounting on a ball-bearing slide, separate cursor keys, frequency-programmable autorepeat for all keys, N-key rollover, and tactile feel. $345.

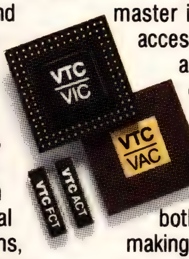
Preh Electronic Industries Inc, 470 E Main St, Lake Zurich, IL 60047. Phone (708) 438-4000. FAX (708) 438-5522.
Circle No. 421

DC/DC Converters

- *Have 2:1 input range*
- *Offer two output choices*

XW Series dc/dc converters accept any input in the range of 9 to 18, 18 to 36, or 36 to 72V. Two output choices are available for each input range—±12V at 1.25A or ±15V at 1A. Efficiencies of 85% at 20% of full load are possible. Key specifications include a 20-mV p-p output noise, 0.02% load regulation, 0.8% long-term output stability, 500V dc isolation, and a −55 to +80°C operating range. An internal limit circuit shuts the converter down when it overheats. When the converter output is not needed, a shutdown pin toggles the unit on and off to conserve power drain. The units

THREE NAMES ARE STACKING UP BIG IN THE BUS BUSINESS.



If you're designing for bus systems, you should know these names. *VIC, VAC,* and *ACL* are IC building blocks that can drive your system to maximum performance levels.

The VIC068 brings real plug-and-play compatibility to the VME world. It's a complete VMEbus Interface Controller on a single chip. Developed with a consortium of VMEbus International Trade Association (VITA) member firms, it's fast becoming the standard for VME developers, worldwide.

Since it's a single-chip solution, the VIC068 gives VME designers more board space for other features. And, it guarantees compatibility for boards from different suppliers.

The VAC068 is a VMEbus Address Controller, designed as a complementary chip to the VIC. It provides address counters and the necessary hand-shaking signals for block transfers. It also provides memory address decoding and, like the VIC chip, is highly programmable. The VAC068 truly raises the level of integration for high-performance systems.

The VIC-VAC architecture provides a complete master interface, with unrestricted memory access to and from the VMEbus. Both chips are packaged in a 144-pin plastic or ceramic PGA.

The VIC and VAC chips drive the bus directly, using the patented output drivers from VTC's ACL (Advanced CMOS Logic) family. Our ACL parts — both FCT and ACT — have up to 64mA drive, making them ideal for *any* high-performance bus system. And, with significantly less ground bounce than competitive products, our FCT gives you better system performance.

VIC, VAC, and ACL are available in commercial and military versions.

And, these three names are just the beginning. There's more to come in the "total VTC bus solution." So, get on board! And start driving *your* system to the maximum.

IN U.S.A., CALL 1-800-VTC-CMOS
(612-851-5200/Fax 612-851-5199/Telex 857113)
France: 01-42042925
Italy: 02-61290521
Netherlands: 20-5495969
Spain: 01-5344000
Sweden: 08-979020
U.K.: 0732-741841
W. Germany: 8071-2722

VTC Incorporated
Hard-Driving Bus Solutions.™

CIRCLE NO. 95

also feature internal transient overvoltage protection devices and noise filters on the input and output. $165.

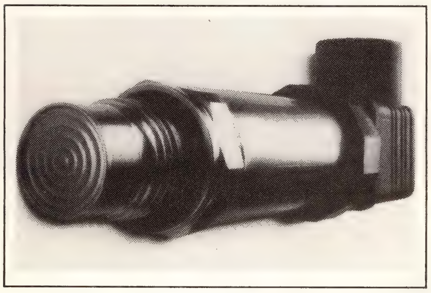
Calex Mfg Co Inc, 3355 Vincent Rd, Pleasant Hill, CA 94523. Phone (800) 542-3355; in CA, (415) 932-3911. FAX (415) 932-6017.

Circle No. 422

Pressure Transmitter

- *Offers an amplified output*
- *Features ±0.25% accuracy*

The ST-420 pressure transmitter measures vacuum, compound, and gauge pressure levels to 15,000 psi and features an overall accuracy of ±0.25%. The stainless-steel package includes the sensor as well as an amplifier, which is encased in a silicone compound for improved vibration resistance. The unit operates from a supply voltage of 10 to 30V and provides a choice of outputs: 2-wire, 4- to 20-mA dc; or 3-wire, 0 to 5V dc. Hysteresis measures 0.1% max, and temperature sensitivity equals −0.005% °F. Operating range spans −20 to +250°F. Electrical connections are via a DIN 43650 terminal strip. From $200.



International Pressure Products, Box 2108, Norcross, GA 30091. Phone (800) 736-7675; in GA, (404) 729-1992. FAX (404) 729-8391.

Circle No. 423

Miniature Relays

- *Can switch 300W*
- *Consume 360 mW max*

G5C miniature relays have a 2500 VA/300W max switching capacity. They handle loads of 10A at 250V ac/30V dc and 15A at 110V ac. The fully sealed construction ensures an electrical service life of 300,000 cycles max. Five models are available: the standard G5C-1, the sealed G5C-14, the high-capacity G5CE-1, the high-sensitivity G5C-1-H, and the low sensitivity G5C-1-L. Coil power consumption ranges from 150 to 360 mW. The relays can withstand voltage surges to 6000V ac, have an initial contact resistance of 30 mΩ, and have an operate and release time of 10 msec. $1.72 (1000).

Omron Electronics Inc, 1 E Commerce Dr, Schaumburg, IL 60173. Phone (708) 843-7900.

Circle No. 424

Programmable Attenuators

- *Have 75Ω impedance*
- *Operate to 1 GHz*

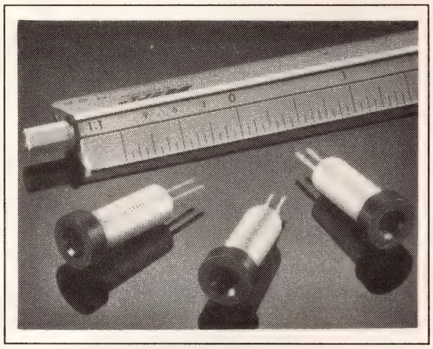
These additions to the MDA Series of programmable attenuators have a 75Ω characteristic impedance and operate over a dc to 1-GHz range. Models are available with attenuation steps as small as 0.1 dB and total attenuation values ranging to 127 dB. Electrical construction uses one EMI/RFI filter per bit; all bits are interconnected to a single common filter of the opposing polarity. Standard control voltage equals 26.5V but other values are available. $220 to $410.

Alan Industries Inc, Box 1203, Columbus, IN 47202. Phone (800) 423-5190. **Circle No. 425**

Panel-Mount LEDs

- *Are IR secure*
- *Conform to DESC requirements*

The HLMP-Zxxx panel-mount, infrared-secure, military-grade LED indicators have night-vision capability. The HLMP-Z490 lamp is yellow, and the HLMP-Z740 lamp is green. The lamps conform to the requirements of the Defense Supply Center (DESC) selected-item drawing 87019, including 100% screening and burn-in. An integral glass night-vision goggle filter mounted within the collar of the lamp sleeve suppresses IR emissions to <0.5% of total emission at all viewing angles. You can achieve the luminance needed for night vision by decreasing the dc forward current or by using a PWM input. $45 (1000).



Hewlett-Packard Co, 19310 Pruneridge Ave, Cupertino, CA 95014. Phone (800) 752-0900.

Circle No. 426

Display Module

- *Operates from 5V*
- *Includes all onboard electronics*

The vacuum-fluorescent 3601-92-020 display has a 20-character line of 0.2-in.-high characters. The onboard character generator provides the standard 96-character ASCII character set and characters that include accented European letters. The unit can also accept downloaded character patterns in a 5×7 dot-matrix format. Module interfacing is via an 8-bit parallel TTL data bus. Both power and data connections, which include hardware reset and busy signals, are on the same connector. In the self-test mode, the unit displays all printable characters from 20 HEX through FF HEX. Power requirements for the display are 5V at 360 mA. $65 (100). Delivery, four to six weeks ARO.

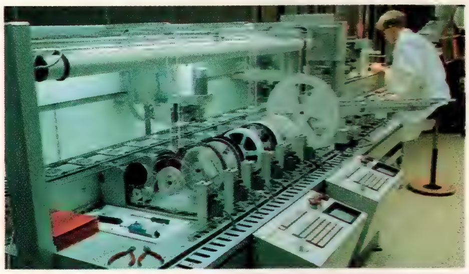
IEE Inc, 7740 Lemona Ave, Van Nuys, CA 91409. Phone (818) 787-0311. FAX (818) 902-3723. TLX 4720556. **Circle No. 427**

Special 1983 reprise edition
Standard components launched in miniature
Stockholm: 'we will sink Russian subs'
Kohl re-elected — but Greens gain gro
Lech Walesa wins Nobel peace prize
Shergar kidnapped
French aid for Chad
EriPower™
On-Card DC/DC Converter
PKA 4211 P
In: -(39-64)V
Out: 5V
Pout: 25W
Made in Sweden
ERICSSON

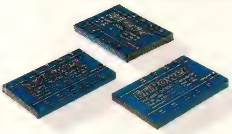
A 1983 concept that's still an innovation - Ericsson component power

If you've only just discovered the economy, reliability and flexibility of component power, don't worry. Even some power supply manufacturers think it's new!

In fact, component power concept - using very efficient, high frequency DC/DC converters as complete power 'components' for distributed power architecture - was introduced by Ericsson way back in 1983. And EriPower™ modules have since been proven in thousands of applications worldwide.



The PKA & PKC, DC/DC converters are produced on fully automated lines to guarantee consistently high quality and reliability



The PKC In-Card, 15-18 Watt DC/DC converters provide ultra low profile

The first product, the PKA 25 to 40 Watt converter, set the standard and is still the market leader by far. Using hybrid construction and 300 kHz switching it's the world's smallest converter to offer full power operation at 85°C. And with ceramic capacitors for filtering and effective thermal management design, it has a demonstrated MTBF of over 200 years!

This same concept applies to the 15 and 18 Watt PKC. With a footprint smaller than a credit card, these sub-miniature converters offer the unique option of In-Card low profile mounting. The mechanical design allows the center of the module to rest in a slot in the PCB, giving a maximum height of just 8.5mm.

The PKA and PKC can be easily paralleled for higher power applications and they make ideal components for n+1 parallel redundancy applications.

If your product demands innovative power supplies, yet needs the security of well proven solutions from a reliable source, call Ericsson. And let our technology lead help maintain yours.

Sweden	Ericsson Components AB, Stockholm, Tel: (08) 721 70 59 Fax: (08) 721 70 01
Australia	Ericsson Components Pty Ltd, Victoria, Tel: (03) 480 12 11 Fax: (03) 484 36 45
France	Ericsson Composants SA, Gyancourt, Tel: (01) 30 64 09 00 Fax: (01) 30 64 11 46
Hong Kong	Ericsson Components AB, Wanchai, Tel: (05) 756 640 Fax: (05) 834 5369
Great Britain	Ericsson Components AB, Coventry, Tel: (0203) 553 647 Fax: (0203) 225 830
Italy	Ericsson Components Srl, Milano, Tel: (02) 551 81 597 Fax: (02) 545 97 31
Norway	Ericsson Components A/S, Oslo, Tel: (02) 6 50 190 Fax: (02) 644 138
United States	Ericsson Components Inc, Richardson, TX, Tel: (214) 480 83 00 Fax: (214) 680 10 59
West Germany	Ericsson Components GmbH, Engen, Tel: (07733) 500 10 Fax: (07733) 5927

ERICSSON

CIRCLE NO. 96

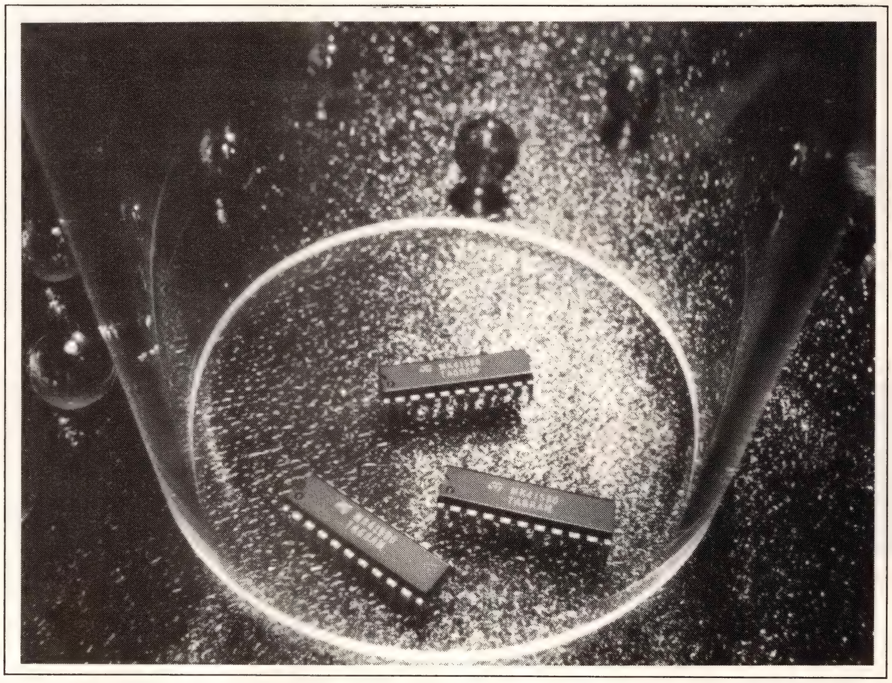
NEW PRODUCTS

INTEGRATED CIRCUITS

16k-Bit Cache Tag RAM

- *Organized as 4k×4 bits*
- *Has 12-nsec access time*

Manufactured using an ultrafast 0.8-µm double-metal CMOS process, the MK41S80 cache Tag RAM features an address-to-compare access time of 12 nsec. Organized as 4k×4 bits, the 16k-bit static RAM (SRAM) is integrated with a 4-bit comparator. The device performs standard SRAM read/write operations and has a flash clear mode for rapid cache flushing, which sets all of the 16k bits to a logic zero. In addition, the device has a compare mode, which internally compares the data in the addressed RAM location with the input (tag) data; a Match output indicates the result of the comparison. The device, which has TTL-compatible inputs and outputs, operates from a single 5V supply. In a 22-pin DIP or 24-pin SOJ package, 12-nsec version, $25; 15-nsec version, $18.75 (1000).

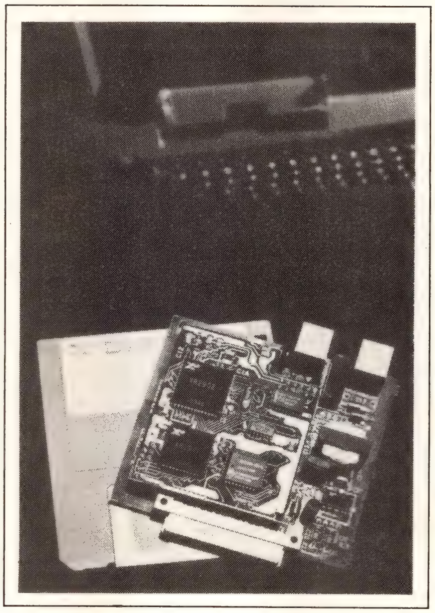


SGS-Thomson Microelectronics, 1000 E Bell Rd, Phoenix, AZ 85022. Phone (602) 867-6100. **Circle No. 398**

2-Chip Set For Fax/Data Modem Function

- *Supports 9600- and 2400-bps applications*
- *Fabricated in low-power CMOS*

The XR-2900 is a 2-chip set that provides the modem data-pump function for 9600-bps half-duplex and 2400-bps full-duplex applications. The chip set provides all of the functions needed for implementing a modem for facsimile or V.29 applications, and it also includes a complete V.22 data modem. The XR-2901, which uses digital signal processing, supports the modulation and demodulation functions. The XR-2902 is a combination analog and digital chip whose analog section supports the transmit and receive filters, A/D and D/A functions, programmable-gain amplifier, and transmit level attenuator. The digital section of the chip supports the transmit clock, the asynchronous/synchronous converter, the interface circuit between the XR-2901 and the host controller, and a receive-clock phase-locked loop. The CMOS XR-2901 and XR-2902 are available in 40- and 48-pin DIPs and 44- and 52-pin plastic leaded-chip carriers, respectively. Chip set, $36.82 (1000).



Exar Corp, 2222 Qume Dr, San Jose, CA 95161. Phone (408) 434-6400. **Circle No. 399**

High-Speed Multiplexer

- *Has eight channels*
- *Features 0.003% accuracy*

The MX-826 8-channel analog multiplexer features high-speed operation and high accuracy. For 14-bit applications, the device has a maximum settling time of 400 nsec to 0.003%, which is equal to ±0.5-LSB accuracy. Settling time for 12-and 10-bit applications is 225 nsec to 0.01% and 150 nsec to 0.1%, respectively. The multiplexer contains an internal buffer amplifier, which provides a wide-bandwidth, low-impedance output for driving data-ac-

Text continued on pg 184

Insist on Interpoint.

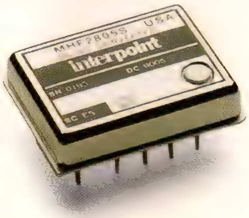
Your dc-dc converter is going to power a system that *can't fail.* But it has to fit in a space the size of a postage stamp. Where can you find that level of power density and reliability? At Interpoint.

Interpoint specializes in putting big performance into small packages. We build our dc-dc converters by mounting components directly on a ceramic substrate and hermetically sealing them in steel. We give them high, constant frequency switching rates for small size, high power density and low noise. Then we screen them to the most rigorous military standards. The result? Converters that are virtually immune to thermal shock, vibration and moisture.

When size and reliability are critical, designers depend on Interpoint. It's been that way for twenty years. That's why we provide board-mounted power for virtually every airliner in the West, advanced fighter aircraft and ground vehicles, the space shuttle, and a host of other military, aerospace and industrial applications.

Each of our new converters raises the standards for performance and reliability. So if your system has a little room for improvement, call Interpoint. **1-800-822-8782, ext.229.** In Europe, call **44-276-26832.**

New! The MHF dc-dc converters give 12 watts power, 30 watts/in^3 power density, 16 to 40 Vdc input, 84% efficiency, 600 kHz constant frequency switching, single or dual outputs at 5, ±12, ±15 Vdc, 0.325 in. high, 1.5 million hrs MTBF (AIT, 45°C), full power over -55 to +125°C temperature range.



interpoint

MIL-STD-1772 QUALIFIED

10301 Willows Road P.O. Box 97005
Redmond, WA 98073-9705

CIRCLE NO. 97

Marilyn, You're The Greatest.

If you asked Marilyn Monroe's fan club who they thought was the greatest screen actress, guess what they would answer. Fans express loyalty above objectivity.

The same is true in publication readership studies. When a publication sends readership questionnaires to its own readers and asks, "Which publication do you read regularly?"—guess what they'll answer! While these studies are not wrong or misconducted, they result in an obvious bias.

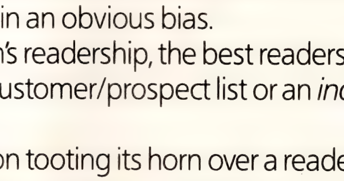
If you're interested in a publication's readership, the best readership studies are conducted across a company's customer/prospect list or an *independent* industry list.

The next time you see a publication tooting its horn over a readership win at a company like IBM, AT&T, or Sun Microsystems—don't be too impressed. With those big-name headlines comes some small print. Take a second to notice where the questionnaires were sent. If it's a publication's own subscriber list then you'll know the study results are nothing more than fan mail.

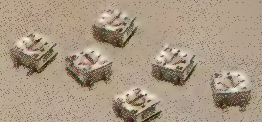
EDN Magazine Edition
News Edition

A Partnership in Power & Prestige
Worldwide

- **EDN has won 84% of all *independent* readership/reader preference studies conducted since 1978. No other electronic engineering magazine or newspaper in the US or throughout the world has won more *independent* readership/reader preference studies than EDN. And, EDN is willing to pay $1000 to anyone who can disprove its claim to leadership in readership.**



BOURNS



Best Trimmer For Worst Case Processing.

The surface mount assembly process subjects components to the most severe environments that they will ever likely encounter.

Bourns Trimpot kept that fact in mind when designing its 4mm sealed Model 3314 trimmer. From placement to soldering to cleaning, this rugged single-turn trimmer is compatible with all popular surface mount manufacturing processes.

Applications versatility also describes the Model 3314. It's ideal for oscilloscopes, power supplies, signal generators, satellites, computers, cellular phones, pagers, video cameras, radar detectors, robotics and more.

The Model 3314 delivers performance too. This trimmer's hoe-tipped multi-wire wiper reduces contact resistance variation and noise. Temperature coefficient is superior, thanks to a stable thick film cermet element. Its silicone rubber O-ring creates a permanent seal with very low backlash.

For applications that require surface mount assembly, plan for the worst by specifying the best... the Bourns Model 3314 trimmer.

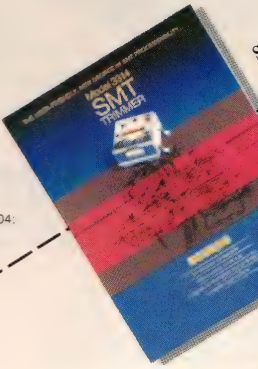
BOURNS®

THERE'S STILL NO EQUIVALENT

Bourns, Inc., 1200 Columbia Avenue, Riverside, California 92507; (714) 781-5500; European Headquarters: Zugerstrasse 74, 6340 Baar, **Switzerland:** 042-333333; **Benelux:** 070-874400; **France:** 01-40033604; **Germany:** 0711-22930; **Ireland:** 021-357001; **United Kingdom:** 0276-692392; Asia Pacific Headquarters: 1401 Citicorp Centre, 14th Floor, 18 Whitfield Road, **Hong Kong:** (852) 5-702171; **Singapore:** (65) 339-3331; **Korea:** (82) 556-3619; Japan Headquarters: 2nd Floor, Time 24 Building, #35 Tansu-cho, Shinijukuku, Tokyo, 162, **Japan:** (03) 260-1411

Circle 33, Send Literature

Circle 32, Call Me



Send to: Bourns, Inc., M/S ADV
1200 Columbia Ave., Riverside, CA 92507

Send me my FREE 3314 brochure and FREE sample offer

Name________

Title________

Company________

Address________

City________

State________ Zip________

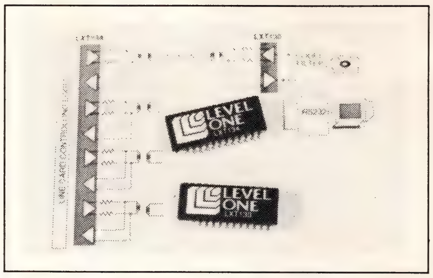
EDN051090

COPYRIGHT © 1989, BOURNS, INC. 7/89

quisition systems. Other specifications include THD of −92 dB at 100 kHz and −83 dB at 1 MHz, and crosstalk of −86 dB at 100 kHz. The device's break-before-make switching ensures that no two channels are ever momentarily shorted together. The analog signal range is ±10V, and input signals as high as ±15V may be present while power to the multiplexer is shut off. Packaged in a 24-pin double DIP, the MX-826 operates from ±15 and 5V supplies. From $100 (100).

Datel Inc, 11 Cabot Blvd, Mansfield, MA 02048. Phone (508) 339-3000. FAX (508) 339-6356.

Circle No. 400



Voice/Data Transceivers

- *Use time-compression multiplexing*
- *Operate over twisted-pair lines*

Using time-compression multiplexing, the single-channel LXT130 and 4-channel LXT134 are integrated transceivers for high-speed (160k-bps) data and digitized voice transmission over unshielded telephone lines. Both devices use a "ping-pong" transmission scheme to achieve full duplex operation over a single twisted-pair line. The devices provide transparent, burst-mode transmission of two 64k-bps B channels, one 16k-bps D channel, and one 16k-bps M channel. The transceivers, which operate from a 5V supply, are effective over a maximum of 1 km (3300 feet) of #24 AWG station cable. In a 24-pin ceramic DIP, the LXT130JC costs $8.10; in a 40-pin ceramic DIP, the LXT134JC costs $22.56 (100).

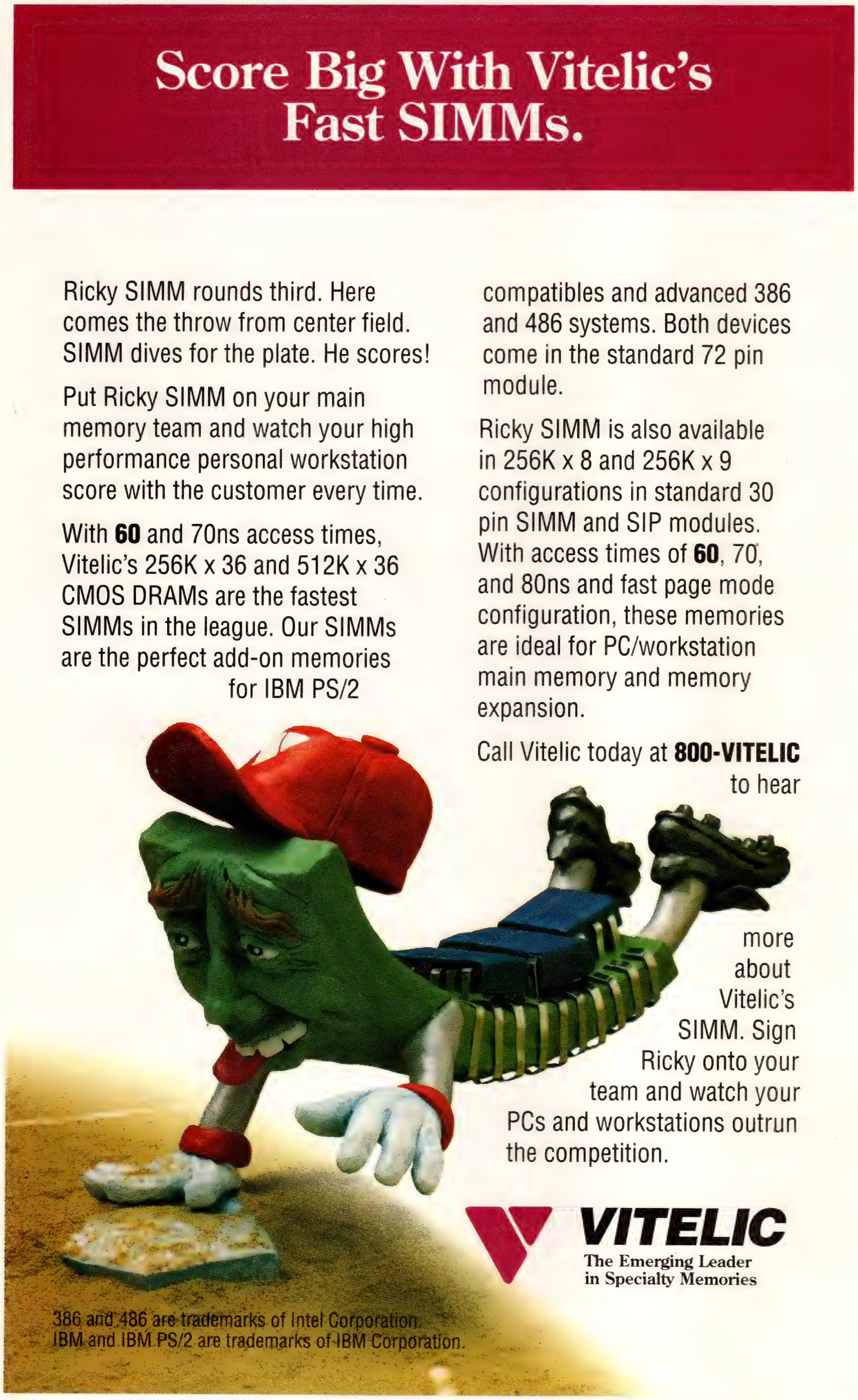
Level One Communications Inc, 105 Lake Forest Way, Folsom, CA 95630. Phone (916) 985-3670.

Circle No. 401

FIR Filter

- *Contains sixteen 16-bit multiplier/accumulators*
- *Sampling rates from 2.5 to 20 MHz*

The PDSP16256 programmable FIR filter contains sixteen 16-bit multiplier/accumulators. The chip's multicycling architecture lets you choose combinations of digital filtering from 16 stages sampled at 20 MHz, to 128 stages sampled at 2.5 MHz. A host CPU or byte-wide EPROM downloads 128 filter coefficients. You can configure the device


Score Big With Vitelic's Fast SIMMs.

Ricky SIMM rounds third. Here comes the throw from center field. SIMM dives for the plate. He scores!

Put Ricky SIMM on your main memory team and watch your high performance personal workstation score with the customer every time.

With **60** and 70ns access times, Vitelic's 256K x 36 and 512K x 36 CMOS DRAMs are the fastest SIMMs in the league. Our SIMMs are the perfect add-on memories for IBM PS/2 compatibles and advanced 386 and 486 systems. Both devices come in the standard 72 pin module.

Ricky SIMM is also available in 256K x 8 and 256K x 9 configurations in standard 30 pin SIMM and SIP modules. With access times of **60**, 70, and 80ns and fast page mode configuration, these memories are ideal for PC/workstation main memory and memory expansion.

Call Vitelic today at **800-VITELIC** to hear more about Vitelic's SIMM. Sign Ricky onto your team and watch your PCs and workstations outrun the competition.

VITELIC
The Emerging Leader in Specialty Memories

386 and 486 are trademarks of Intel Corporation.
IBM and IBM PS/2 are trademarks of IBM Corporation.

Circle 39 for Literature **Circle 40 for Sales Contact**

For debugging, nothing stacks up to VRTX Velocity.

Debugging without VRTX Velocity.

Debugging with VRTX Velocity.

When it comes to debugging real time systems, Ready Systems VRTX® Velocity is the best integrated solution available on UNIX platforms. And the only solution that allows you to debug multiple boards simultaneously.

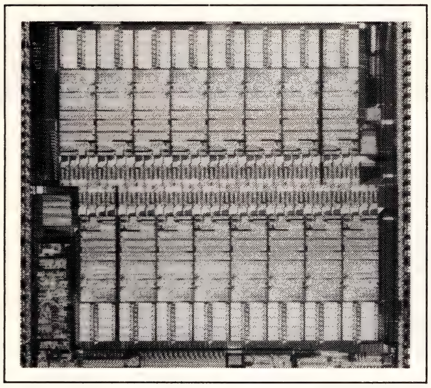
By combining the UNIX development environment, networking capabilities, compiler and debugging tools in one package, VRTX Velocity gives you a completely integrated and totally networked development environment.

Velocity's windowing interface allows you to debug multiple tasks and target processors simultaneously, each in its own window. At the source, assembly and system level.

To find out more, call 1-800-228-1249 or from Texas, 1-214-661-9526. We'll send you a stack of information on the fastest way to get rid of a stack of you-know-what.

READY
SYSTEMS
Real Time for the Real World.

© 1990 Ready Systems Corporation. VRTX is a registered trademark of Ready Systems.



as one long filter or as two half-length filters for filtering complex data. A custom-filter design package, suitable for IBM PC/ATs and compatibles, includes a behavioral model and coefficient-optimization routines. Samples are available now in a 144-pin, pin-grid-array package. £200 (1000).

Plessey Semiconductors Ltd, Cheney Manor, Swindon SN2 2QW, UK. Phone (793) 5128000. FAX (793) 518411. **Circle No. 402**

Single Chip That Combines DSP With ADC And DAC

- *Optimized for mixed-signal processing*
- *Code compatible with the 2100 DSP series*

Combining a digital signal processor (DSP) with A/D and D/A converters, the ADSP-21msp50 is optimized for mixed-signal applications such as telecommunications, digital mobile radio, active noise cancellation, and voice-band signal processing. Code compatible with the company's ADSP-2100 fixed-point DSP series, the monolithic chip incorporates a variety of useful functions. The analog section, which uses sigma-delta conversion, contains a 2-channel ADC, a single-channel DAC, a programmable-gain (−15 dB to +6 dB) amplifier, and anti-aliasing filters. The 16-bit converter has a typical S/N ratio and THD of 65 dB. The digital section includes two data-address registers, a program sequencer, and three computation units (MAC, ALU, and barrel shifter). Also included is 2k × 24 bits of program memory and 1k × 16 bits of data memory (both static RAM), two synchronous serial ports, a wait-state generator, a 16-bit timer, and an 8/16-bit host-interface port. The ADSP-21msp50 is packaged in a 132-pin quad flatpack and will be available for sampling in July. $30 in OEM quantities.

Analog Devices, DSP Div, Box 9902, Norwood, MA 02062. Phone (617) 461-3672. **Circle No. 403**

Dual Op Amp That Features Chopper Stabilization

- *Offset is only 5 μV*
- *Has low-frequency noise of 1.5 μV p-p*

Featuring on-chip sample-and-hold capacitors, the LTC1051 dual op

[redacted]

Be An Author!

When you write for EDN, you earn professional recognition. And you earn $75 per published magazine page.

EDN publishes how-to design application information that is read by more than 137,300 electronics engineers and engineering managers worldwide. That's an audience that could belong to you.

If you have an appropriate article idea, send your proposal and outline to:
Joan Morrow , 275 Washington Street, Newton, MA 02158-1630.

For a FREE EDN Writer's Guide—which includes tips on how to write for EDN and other technical publications—please circle number 800 on the Information Retrieval Service Card.

EDN *First in Readership among Design Engineers and Engineering Managers in Electronics.*

[redacted]

It Takes One To Know 1µm.

And, Mitsubishi is the only one who reduced 1µm gate width to a size that's small enough to provide a low, 5µW power dissipation (the lowest you can get), lower operating temperature and small die size. Plus, we're the only supplier to give you performance as fast as 370 picoseconds and four speed/power options: x1, x2, x3, and x4. So, you can optimize your circuit for *both* fast speed *and* low power. By taking advantage of Mitsubishi's smaller cell sizes, you achieve low operating temperature, more-cost effective silicon use and smaller die size. And, all this means we can help you put your designs in smaller, lower-cost plastic packages and achieve higher reliability. Plus, our selectable output buffer drive and slew rate control help reduce noise and electromagnetic radiation. Mitsubishi offers 70,000 gates (50% utilization); patented* gate isolation structure for faster performance, and extensive packaging options, including plastic QFPs, very-fine-pitch QFPs (VQFPs), PLCCs and APGAs (adaptable pin-grid-arrays). And, of course, we give you 100% burn-in, 100% AC and DC testing, a library of more than 500 cells and design kits for the industry's leading-edge CAE design tools. It takes one solid, proven semiconductor supplier to know 1µm. We're one of the top ten worldwide semiconductor manufacturers, and the world's fifth largest MOS memory manufacturer. We've been producing gate arrays since 1976 and offer production capacities surpassed by none. So, we'll get you through 1µm design, prototype and production *fast* and *right the first time*. Also, keep in mind, a good 1µm will get you to a great 0.8µm! Call the one it takes to know 1µm today at **1-800-624-8999 #178.**

We're The Only One With 5µW And Four Speed/Power Options.

*U.S. Patent No. 4,562,453

MITSUBISHI
GATE ARRAYS

CIRCLE NO. 99

AT&T's new datacom ICs take the high cost out of high speed.

AT&T's new 41 Series of differential quad line drivers/receivers and dual transceivers reach 400 Mb/s with substantially reduced EMI.

Our new datacom ICs do more than offer one of the industry's highest data rates and shortest propagation delays.

Their unique design can take you to 400 Mb/s on common twisted pair—at low EMI levels. This makes them an affordable alternative to fiber, when fiber's other benefits aren't needed.

In system use, they decrease EMI levels up to 30 db compared with standard 26LS TTL ICs. This sharply reduces cabinet design costs. And they meet ESDI standards, making them ideal for disk drive applications.

41 Series devices are pin-for-pin compatible with 26LS ICs—so they're easy to use. They help reduce board complexity and cost via on-chip termination and line-impedance-matching resistors. And they come in space-efficient, surface-mount SOJ and SOIC packages as well as standard DIPs.

Not exactly what you need? Create your own custom version quickly and easily by using our standard cell library.

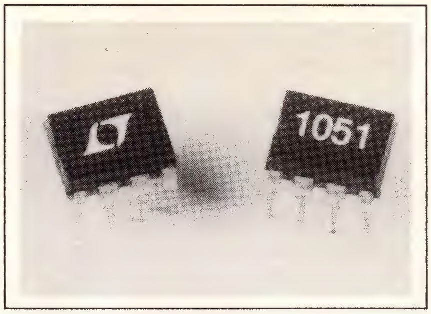
Call 1 800 372-2447 for our databook on 41 Series components, in stock today at Hamilton/Avnet and Schweber.

The components of success.

© 1990 AT&T © The Walt Disney Company

AT&T
The right choice.

CIRCLE NO. 123



amp saves board space and eliminates the need for four expensive capacitors. The device features an offset voltage of 5 μV max and offset drift of 0.05 μV/°C. Low-frequency noise is only 1.5 μV p-p over the 0.1- to 10-Hz range, and the typical voltage gain is 160 dB. With a maximum supply current of only 1 mA per amplifier, the op amp achieves a slew rate of 4V/μsec and a gain-bandwidth product of 2.5 MHz. Other specifications include a CMRR of 114 dB and a PSRR of 120 dB. The dual op amp, which operates from a single 4.75 to 16V supply, is available in an 8-pin plastic or ceramic DIP and in a 16-pin SO package. From $4.25 (100).

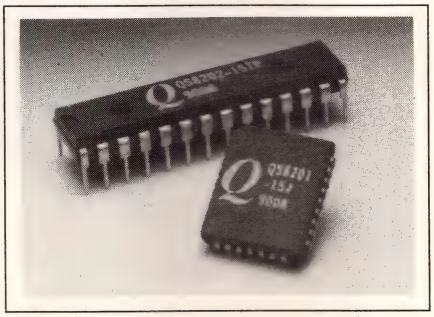
Linear Technology Corp, 1630 McCarthy Blvd, Milpitas, CA 95035. Phone (408) 432-1900. FAX (408) 434-0507. **Circle No. 404**

Error-Correcting Codec

- *Implements Reed-Solomon code*
- *Corrects as many as eight full-byte errors*

The L64710, which integrates both coder and decoder functions in a single device, supports full-duplex operation. The codec inputs and outputs data one byte at a time at data rates of either 30 or 40 MHz, which correspond to serial rates of 240M or 340M bps. The device implements the Reed-Solomon code, which enables it to correct as many as eight full-byte errors in a transmitted message block. The Reed-Solomon code works by appending a redundant check code of 16 bytes to each message block. The L64710's message block is variable from 38 to 239 bytes. At the maximum message length of 239 bytes, redundancy is only 6.5%. Initially available in a 68-pin, ceramic pin-grid-array package. 30-MHz version, $364 (100).

LSI Logic Corp, 1551 McCarthy Blvd, Milpitas, CA 95035. Phone (408) 433-7593. **Circle No. 405**



FIFO Memories

- *Feature 15-nsec speeds*
- *Available in two organizations*

Featuring 15-nsec access times, these CMOS FIFO memory chips are available in two organizations. The QS8201 is organized as 512×9 bits; the QS8202 is organized as 1k×9 bits. The flag bits of the FIFOs have the same access times as the data bits, which eases external timing requirements. The devices use 6-transistor cells, thus eliminating static-hold problems sometimes found in devices having 4-transistor cells. Package options include 28-pin plastic DIP, 28-pin ceramic DIP, 28-pin SOIC, and 32-lead LCC and PLCC (plastic leaded-chip carrier). In 300-mil plastic DIP, QS8201, $45; QS8202, $60 (100).

Quality Semiconductor Inc, 2946 Scott Blvd, Santa Clara, CA 95054. Phone (408) 986-1700. FAX (408) 496-0773. **Circle No. 407**

AT&T's Datacom ICs: high-speed, low EMI performance

Chart below shows resultant data rates when using a 41 Series driver with various lengths of 26 AWG twisted pair cable terminated with a 41 Series receiver in split termination. Maximum bit rate is the point at which the 41 Series receiver output data eye is reduced 20% from ideal.

MAXIMUM DATA RATE VERSUS LINE LENGTH

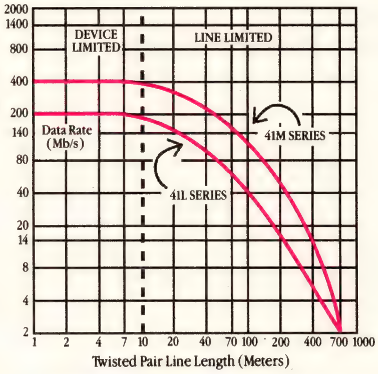


Chart below compares typical propagation delay of AT&T's 41 Series devices to industry standard 26LS and DS8923A devices.

PROPAGATION DELAY (ns)

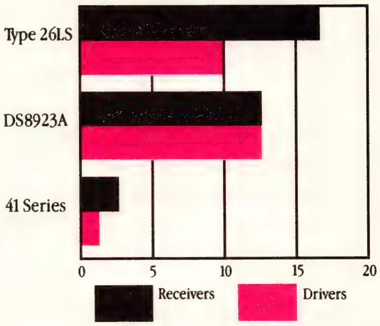
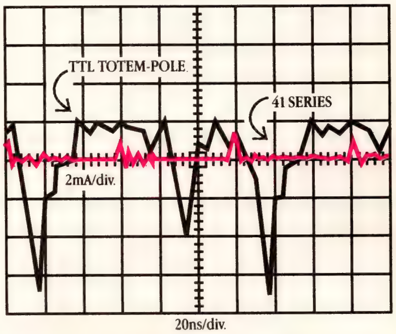


Chart below compares the driver common mode output current levels for the 41 Series and available industry TTL equivalents. Lower Icm results in low EMI.

COMMON-MODE CURRENTS



CIRCLE NO. 145

NEW PRODUCTS

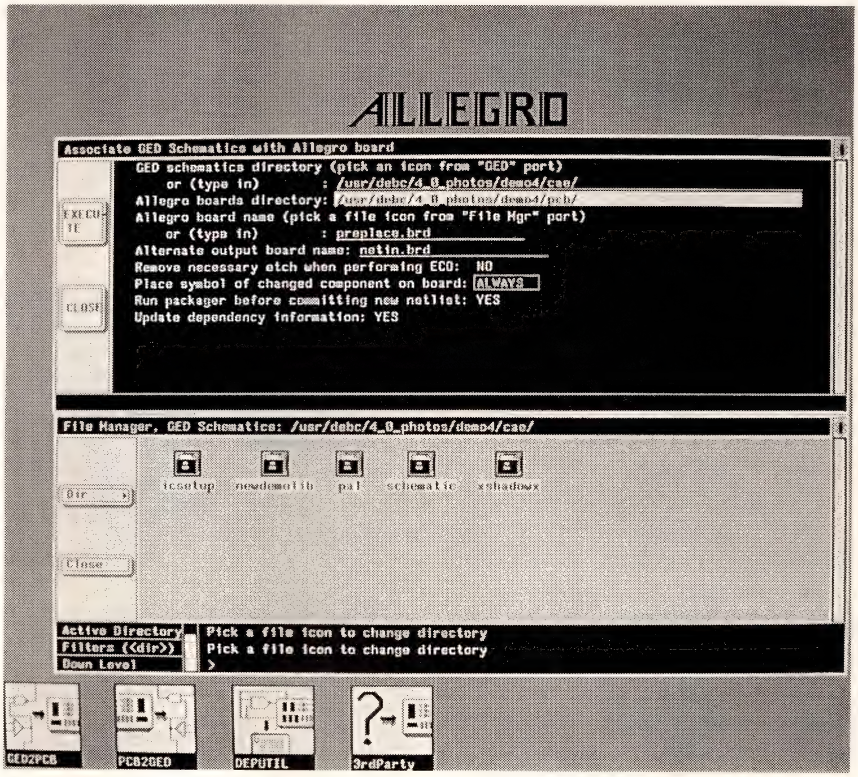
CAE & SOFTWARE DEVELOPMENT TOOLS

Integrated PC-Board-Design And -Analysis System

- *Synchronization between design and layout databases*
- *Provides a common multitool user interface*

Allegro 4.0 now includes framework technology that allows engineers and layout designers to concurrently manipulate engineering schematics and layout, while automatically tracking dependencies between the design and layout databases. A design-dependency manager monitors each change made to the schematic and provides a mechanism for updating the layout data. Likewise, if you initiate an engineering-change order (ECO) at the layout stage, the design-dependency manager automatically flags any changes to the schematic that are needed. A communications manager further integrates Allegro with the vendor's ValidGED schematic-capture system. A common user interface, which is icon-and form-driven, allows you to send netlist information and back-annotation data between the schematic and layout tools. You can, for example, select and view nets on the schematic and simultaneously view the corresponding traces on the layout in a separate window. In addition, optional features let you import databases and symbol libraries from Scicards or Cadnetix systems. The system runs on Sun-3 and Sun-4 workstations, VAXstations and DECstations, and the IBM RISC System/6000. $20,000 to $50,000, depending on the software configuration.

Valid Logic Systems, 2820 Orchard Pkwy, San Jose, CA 95134. Phone (408) 432-9400. FAX (408) 432-9430. **Circle No. 390**



```
Associate GED Schematics with Allegro board
GED schematics directory (pick an icon from "GED" port)
    or (type in)          : /usr/debc/4_0_photos/demo4/cae/
Allegro boards directory: /usr/debc/4_0_photos/demo4/pcb/
Allegro board name (pick a file icon from "File Mgr" port)
    or (type in)          : preplace.brd
Alternate output board name: netin.brd
Remove necessary etch when performing ECO:  NO
Place symbol of changed component on board: ALWAYS
Run packager before committing new netlist: YES
Update dependency information: YES
```

```
File Manager, GED Schematics: /usr/debc/4_0_photos/demo4/cae/
Active Directory   Pick a file icon to change directory
Filters (<dir>)    Pick a file icon to change directory
Down Level         >
```

Digital Scope Program For The Macintosh

- *Turns your Macintosh into a digital oscilloscope*
- *Can analyze waveforms with more than 10,000 points*

IntuScope for the Mac is a data-analysis program that behaves like an advanced digital oscilloscope. With 1M byte of RAM, the program can analyze waveforms with more than 10,000 points; the size of the waveforms is limited only by the amount of RAM in the computer. You can print graph windows and data measurements, or you can transfer them to desktop-publishing programs for display. Built-in Spice options allow you to display ac-, dc-, and transient-analysis data. Using multiple windows, you can select, view, and compare waveforms from several sources, and you can perform cursor-based measurements, arithmetic, and transformations on each waveform. The program runs on all Macintosh computers with 1M or more bytes of RAM. $325.

Intusoft, Box 6607, San Pedro, CA 90734. Phone (213) 833-0710. FAX (213) 833-9658.

Circle No. 391

DSP Software For IBM PCs And Compatibles

- *New features include rubber-band-mode waveform editing*
- *Comes with device drivers for analog and DSP boards*

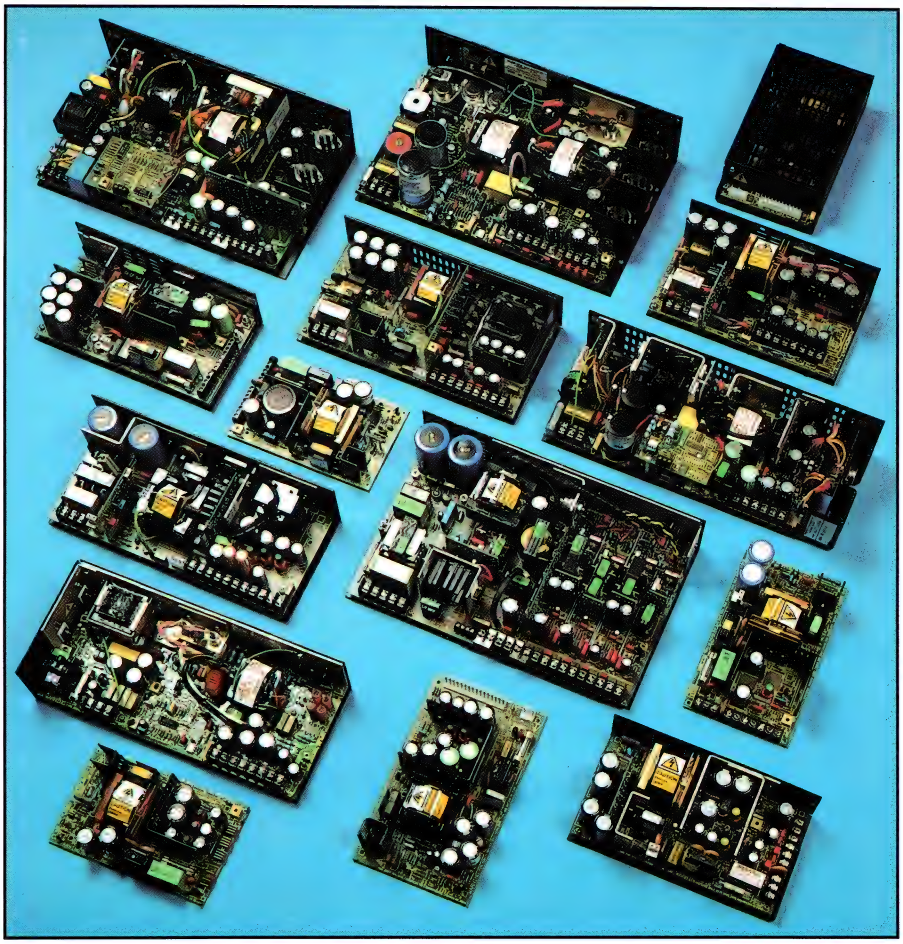
Hypersignal-Workstation version 2.0 is a DSP software package that runs on IBM PCs, PS/2s, and compatibles. New features and enhancements include alternative floating-point waveform storage formats, accelerated processing and display rates, rubber-band mode as well as cut-and-paste mode for

Text continued on pg 194

NEW. Open frame, "N" Range switch mode power supplies from Farnell Advance.

The Farnell "N" Range of open frame, 50 to 500-watt, switch mode power supplies offers electronic designers a wide choice of single and multiple output units, featuring technically superior designs and the highest standards of production quality. Refer to the listing of available standard models and contact Farnell Advance, 32111 Aurora Rd., Solon, OH 44139 for specifications.

PHONE: (216) 349-0755.
FAX: (216) 349-0142.



FCC

FARNELL ADVANCE
POWER

Output Power	Output 1	Output 2	Output 3	Output 4	Output 5	Package Options	Dimensions including covers	Model No.
50 watts multi output	+5V 6A	+12V 1A	+24V 1A	-5V 1A	-12V 1A	2,3	*a	N50R110
	+5V 6A	+15V 1A	+24V 1A	-5V 1A	-15V 1A	2,3	*a	N50R201
55 watts single output	5V 11A	—	—	—	—	1,3,4	b	NS055005
	12V 4.6A	—	—	—	—	1,3,4	b	NS055012
	15V 3.7A	—	—	—	—	1,3,4	b	NS055015
	24V 2.3A	—	—	—	—	1,3,4	b	NS055024
	30V 1.8A	—	—	—	—	1,3,4	b	NS055030
	48V 1.15A	—	—	—	—	1,3,4	b	NS055048
	56V 1A	—	—	—	—	1,3,4	b	NS055056
55 watts multi output	100V 0.55A	—	—	—	—	1,3,4	b	NS055100
	+5V 3.5A	+12V 3A(S)	-12V 1A(S)‡‡	—	—	1,3,4	b	NA055P300
	+5V 3.5A	+12V 3A(S)	+24V 1A(S)‡‡	—	—	1,3,4	b	NA055P301
	+5V 3.5A	+15V 3A(S)	-15V 1A(S)‡‡	—	—	1,3,4	b	NA055P302
	+5V 6A	+12V 3A(S)	F12V 2A(S)	F24V 1A(S)	—	1,3,4	c	NA055P400
	+5V 6A	+12V 3A(S)	F12V 2A(S)	F5V 1A(S)	—	1,3,4	c	NA055P401
	+5V 6A	+15V 3A(S)	F15V 2A(S)	F24V 1A(S)	—	1,3,4	c	NA055P403
	+5V 6A	+12V 3A(S)	F12V 1A	F12V 1A	—	1,3,4	c	NA055P413
75 watts single output	5V 15A	—	—	—	—	1,3,4	*d	NS075005
	12V 6.25A	—	—	—	—	1,3,4	*d	NS075012
	15V 5A	—	—	—	—	1,3,4	*d	NS075015
	24V 3.2A	—	—	—	—	1,3,4	*d	NS075024
	30V 2.5A	—	—	—	—	1,3,4	*d	NS075030
	48V 1.6A	—	—	—	—	1,3,4	*d	NS075048
75 watts multi output	56V 1.4A	—	—	—	—	1,3,4	*d	NS075056
	+5V 8A	+12V 3A(S)	F12V 2A(S)	—	—	1,3,4	e	NA075P300
	+5V 8A	+12V 3A(S)	F12V 2A(S)	F24V 1A	—	1,3,4	e	NA075P400
	+5V 8A	+12V 3A(S)	F12V 2A(S)	F5V 1A	—	1,3,4	e	NA075P401
	+5V 8A	+12V 3A(S)	+12V 2A(S)‡	-12V 0.5A‡	—	1,3,4	e	NA075P402
	+5V 8A	+15V 3A(S)	F15V 2A(S)	F24V 1A	—	1,3,4	e	NA075P403
	+5V 8A	+12V 3A(S)	-12V 1A‡	-5V 1A‡	—	1,3,4	e	NA075P414
90 watts multi output	+5V 10A	+12V 5A	-12V 2A	-5V 1A	+24V 1A	2,3	*f	N90R109
	+5V 10A	+15V 5A	-15V 2A	-5V 1A	+24V 1A	2,3	*f	N90R132

CIRCLE NO. 150

FARNELL ADVANCE OPEN-FRAME SWITCH MODE POWER SUPPLIES

Output Power	Output 1	Output 2	Output 3	Output 4	Output 5	Package Options	Dimensions including covers	Model No.
110 watts single output	5V 22A or 30A(FC)	—	—	—	—	2,3,4	*g	NS110005
	12V 9.2A or12.5A(FC)	—	—	—	—	2,3,4	*g	NS110012
	15V 7.5A or10A(FC)	—	—	—	—	2,3,4	*g	NS110015
	24V 4.6A or 6.25A(FC)	—	—	—	—	2,3,4	*g	NS110024
	30V 3.7A or 5A(FC)	—	—	—	—	2,3,4	*g	NS110030
	48V 2.3A or 3A(FC)	—	—	—	—	2,3,4	*g	NS110048
	56V 2A or 2.6A(FC)	—	—	—	—	2,3,4	*g	NS110056
110 watts multi output	+5V 12A	+12V 6A(S)	-12V 3A(S)‡‡	—	—	2,3,4	h	NA110P300
	+5V 12A	+15V 6A(S)	-15V 3A(S)‡‡	—	—	2,3,4	h	NA110P302
	+5V 10A	+12V 1.5A(S)‡‡	+12V 3.5A(S)	-12V 0.7A(S)‡‡	—	2,3,4	h	NQ110P400
	+5V 12A	+12V 5A(S)	-12V 2A(S)‡‡	—	+24V 2A(S)‡	2,3,4	*i	NA110P400
	+5V 12A	+12V 5A(S)	-12V 2A(S)‡‡	-5V 1A‡‡	—	2,3,4	*i	NA110P401
	+5V 12A	+12V 5A(S)	+12V 3A(S)‡‡	—	-12V 2A(S)‡	2,3,4	*i	NA110P402
	+5V 12A	+15V 5A(S)	-15V 2A(S)‡‡	—	+24V 2A(S)‡	2,3,4	*i	NA110P403
	+5V 12A	+12V 5A(S)	-12V 2A(S)‡‡	-5V 1A‡‡	+24V 2A(S)‡	2,3,4	*i	NA110P500
	+5V 12A	+12V 5A(S)	-12V 2A(S)‡‡	-5V 1A‡‡	+12V 2A(S)‡	2,3,4	*i	NA110P501
	+5V 12A	+15V 5A(S)	-15V 2A(S)‡‡	-5V 1A‡‡	+24V 2A(S)‡	2,3,4	*i	NA110P503
140 watts single output	5V 28A	—	—	—	—	2,3,4	*g	NS140005
	12V 12A	—	—	—	—	2,3,4	*g	NS140012
	15V 10A	—	—	—	—	2,3,4	*g	NS140015
	24V 6A	—	—	—	—	2,3,4	*g	NS140024
	30V 5A	—	—	—	—	2,3,4	*g	NS140030
	48V 3A	—	—	—	—	2,3,4	*g	NS140048
	56V 2.5A	—	—	—	—	2,3,4	*g	NS140056
140 watts multi output	+5V 17A	+12V 7A(Q)	F12V 3A(Q)	—	—	2,3,4	*j	NA140P300
	+5V 17A	+12V 5A(Q)	F12V 3A(Q)	F24V 3A(Q)	—	2,3,4	*j	NA140P400
	+5V 17A	+12V 5A(Q)	F12V 3A(Q)	—	F5V 1.5A	2,3,4	*j	NA140P401
	+5V 17A	+12V 5A(Q)	F12V 3A(Q)	F12V 1.5A	—	2,3,4	*j	NA140P402
	+5V 17A	+12V 5A(Q)	F12V 3A(Q)	F24V 3A(Q)	F5V 1A	2,3,4	*j	NA140P500
	+5V 17A	+12V 5A(Q)	F12V 3A(Q)	F12V 1.5A	F5V 1A	2,3,4	*j	NA140P501
	+5V 17A	+15V 5A(Q)	F15V 3A(Q)	F24V 3A(Q)	F5V 1A	2,3,4	*j	NA140P503
180 watts multi output and 48 volt D.C. input	+5V 20A	+12V 5A(S)	-12V 5A(S)	+24V 2A(S)	-5V 1A(S)	2,3,4	*k	ND180P500
	+5V 25A	+15V 1A	-15V 1A	—	—	2,3,4	*k	ND180P810
200 watts multi output	+5V 30A	+12V 7A(Q)	F12V 5A(Q)	—	—	2,3,4	*l	NA200P300
	+5V 30A	+12V 7A(Q)	F12V 5A(Q)	F24V 3A(Q)	—	2,3,4	*l	NA200P400
	+5V 30A	+12V 7A(Q)	F12V 5A(Q)	—	F5V 1A	2,3,4	*l	NA200P401
	+5V 30A	+12V 7A(Q)	F12V 5A(Q)	F12V 1.5A	—	2,3,4	*l	NA200P402
	+5V 30A	+12V 7A(Q)	F12V 5A(Q)	F24V 3A(Q)	F5V 1A	2,3,4	*l	NA200P500
	+5V 30A	+12V 7A(Q)	F12V 5A(Q)	F12V 5A(Q)	F5V 1A	2,3,4	*l	NA200P501
	+5V 30A	+12V 7A(Q)	F12V 5A(Q)	F12V 5A(Q)	F5V 5A(Q)	2,3,4	*l	NA200P502
	+5V 30A	+15V 7A(Q)	F15V 5A(Q)	F24V 3A(Q)	F5V 1A	2,3,4	*l	NA200P503
	F5V 30A	F12V 5A	F12V 5A	—	—	2,3,4	*l	NA200R300
	F5V 30A	F12V 5A	F24V 3A	—	—	2,3,4	*l	NA200R301
	F5V 30A	F15V 4.5A	F15V 4.5A	—	—	2,3,4	*l	NA200R303
	F5V 30A	F24V 3A	F24V 3A	—	—	2,3,4	*l	NA200R304
240 watts single output	5V 48A	—	—	—	—	2,3,4	*m	NS240005
	12V 20A	—	—	—	—	2,3,4	*m	NS240012
	15V 16A	—	—	—	—	2,3,4	*m	NS240015
	24V 10A	—	—	—	—	2,3,4	*m	NS240024
	30V 8A	—	—	—	—	2,3,4	*m	NS240030
	48V 5A	—	—	—	—	2,3,4	*m	NS240048
	56V 4.5A	—	—	—	—	2,3,4	*m	NS240056
300 watts multi output (FC)	+5V 40A	+12V 5A	-12V 5A	+24V 5A	-5V 1A	2,3,4	*n	N300R113U
	+5V 40A	+15V 5A	-15V 5A	+24V 5A	-5V 1A	2,3,4	*n	N300R135U
	F5V 40A	F12-24V 6A(8Apk)	F12-16V 6A(8Apk)	F12-16V 6A(8Apk)	F5-15V 4A(5Apk)	2,3,4	*o	NF300R500
	F5V 40A	F12-16V 6A(8Apk)	F48-56V 5A	F12-16V 6A(8Apk)	F5-15V 4A(5Apk)	2,3,4	*o	NF300R505
300 watts multi output and 48 volt D.C. input (FC)	+5V 40A	+12V 5A	-12V 5A	+24V 5A	-5V 1A	2,3,4	*n	ND300R801
	+5V 40A	+12V 5A	-12V 5A	-50V 5A	-5V 1A	2,3,4	*n	ND300R505
500 watts multi output (FC)	F5V 60A	F12-24V 6A(8Apk)	F12-16V 10A (12Apk)	F12-16V 6A(8Apk)	F5-15V 4A(5Apk)	2,3,4,5	*o+	NF500R500
	F5V 60A	F12-16V 6A(8Apk)	F48-56V 5A	F12-16V 6A(8Apk)	F5-15V 4A(5Apk)	2,3,4,5	*o+	NF500R505

CODES

(S) = Semi regulated (otherwise output is fully regulated)
See specification sheets for further detail.
(Q) = Quasi regulated (otherwise output is fully regulated)
See specification sheets for further detail.
F = Output is supplied floating
‡‡ = Can be supplied in opposite polarity to special order.
‡ = Floating or in opposite polarity to special order.
* = Localized areas may exceed these dimensions
(eg terminal cover). Consult full outline drawings.
(FC)=Forced air Cooling at 1 meter/sec is required.
1 = PCB only.
2 = Mounted on L chassis.
3 = Fully cased (add suffix 'M' to end of model number).
4 = Customized enclosure to special order.
5 = Fully cased with integral fan.

DIMENSIONS (in inches)

	LENGTH	WIDTH	HEIGHT
a	7.19	4.32	2.00
b	6.50	4.15	2.13
c	7.19	4.41	2.13
d	7.19	4.41	2.41
e	7.98	4.72	2.41
f	10.53	4.63	2.36
g	8.30	4.53	2.36
h	7.99	4.43	2.36
i	8.28	4.53	2.36
j	9.74	5.00	2.36
k	10.91	4.93	2.83
l	10.49	4.79	2.76
m	9.76	5.91	2.61
n	12.02	7.59	2.95
o	11.81	7.48	2.56
o+ If Integral fan is required			4.06

Unless noted by "(FC)", power ratings are with convection cooling. Forced Cooling will increase output capacity by 25% on the average.

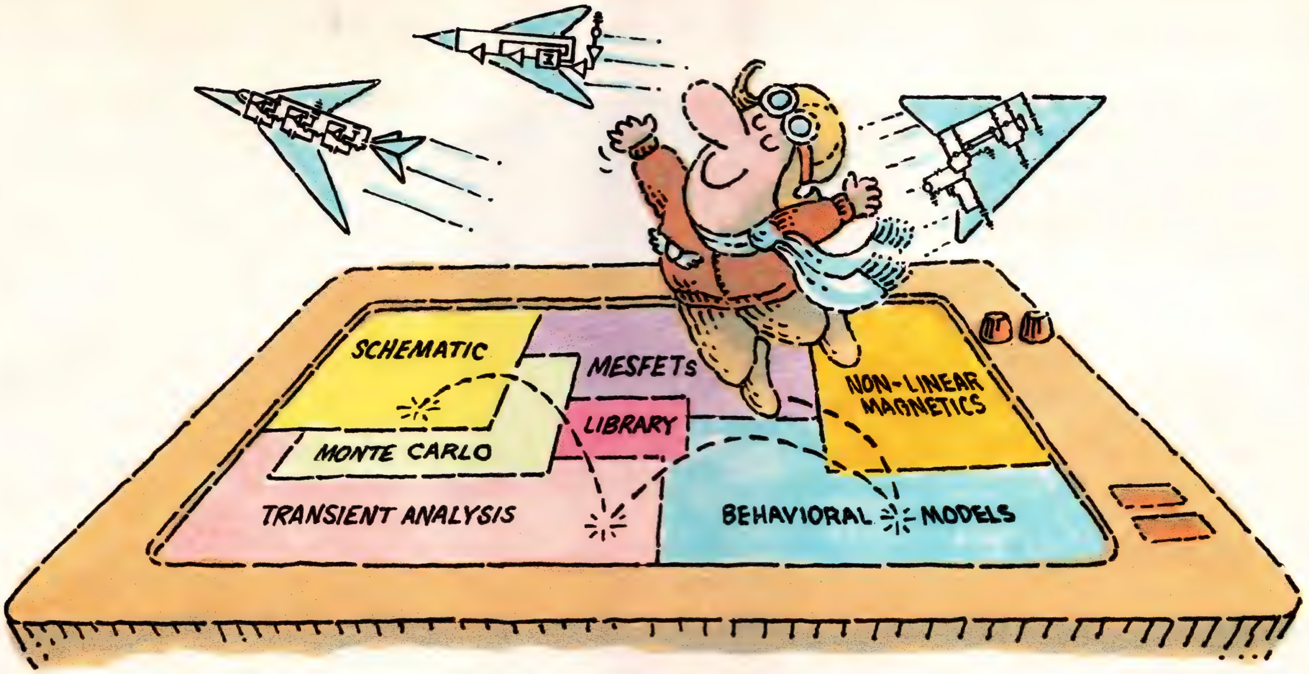
FARNELL ADVANCE
POWER

Advance Power Supplies, Inc.
32111 Aurora Road
Solon, Ohio 44139

PHONE (216) 349-0755.
FAX: (216) 349-0142.

703-022

CIRCLE NO. 150



THE NEW MICRO-CAP III.™ SO YOU CAN TEST-FLY EVEN MORE MODELS.

It wasn't easy. But we did it. Made the long-time best-selling IBM® PC-based interactive CAE tool even better.

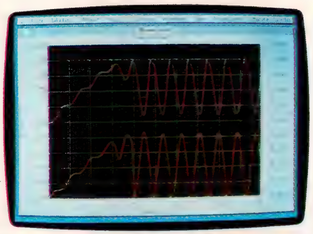
Take modeling power. We've significantly expanded math expression capabilities to permit comprehensive analog behavioral modeling. And, beyond Gummel Poon BJT and Level 3 MOS, you're now ready for nonlinear magnetics modeling. Even MESFET modeling.

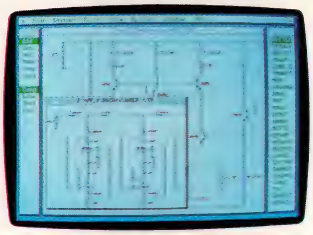
Analysis and simulation is faster, too. Because the program's now in "C" and assembly language. That also means more capacity—for simulating even larger circuits.

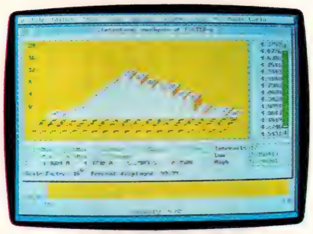
As always, count on fast circuit creation, thanks to window-based operation and a schematic editor. Rapid, right-from-schematics analysis—AC, DC, fourier and transient—via SPICE-like routines. The ability to combine digital/analog circuit simulations using integrated switch models and parameterized macros. And stepped component values that streamline multiple-plot generation.

And don't forget MICRO-CAP III's extended routine list—from impedance, Nyquist diagrams and BH plots to Monte Carlo for statistical analysis of production yield. The algebraic formula parsers for plotting virtually any function. The support for Hercules, CGA, MCGA, EGA and VGA displays. Output for plotters and laser printers.

Cost? Still only $1495. Evaluation versions still only $150. Brochure and demo disk still free for the asking. Call or write for yours today. And see how easily you can get ideas up and flying.


Transient analysis


Schematic editor


Monte Carlo analysis

spectrum

1021 S. Wolfe Road
Sunnyvale, CA 94086
(408) 738-4387

CIRCLE NO. 107

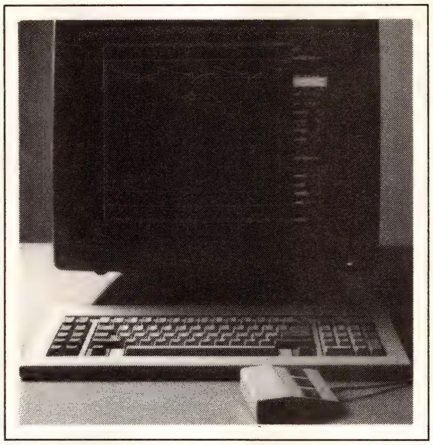
waveform editing, a 3-D map-mode display, and a new stimulus/response mode for D/A and A/D measurements. The package comes with device drivers for a variety of DSP and analog boards, including the Motorola DSP56001 development board. You can use the package with 800×600, 1024×768, and 1600×1200 graphics subsystems, as well as with the NEC PC9800 system. $989.

Hyperception, 9550 Skillman, LB 125, Dallas, TX 75243. Phone (214) 343-8525. **Circle No. 392**

Mixed-Mode Simulator

- *Logic simulator provides timing and board-level analysis*
- *Analog simulator performs three types of analysis*

The Mixed-Mode Simulator works in conjunction with the vendor's EE Designer III design system. This module models both logic and analog components, which can be connected in the same circuit. The program analyzes the circuit in the time domain and plots the results as they would appear on a digital oscilloscope. When the analysis is complete, you can display as many as eight of the resultant waveforms on the screen or plot them on a graphics printer. The Mixed-Mode Simulator model is available at $1495 as part of the EE Designer III package, which includes a schematic-capture editor. It is also available in the $5995 EE Designer III/E package, which consists of schematic-capture, simulation, layout, thermal-analysis, and bill-of-materials generation modules.



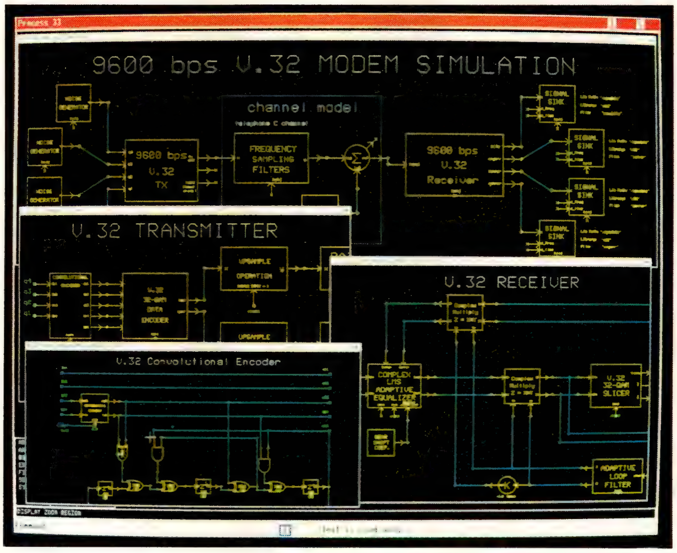
Visionics Corp, 3032 Bunker Hill Lane, Suite 201, Santa Clara, CA 95054. Phone (800) 553-1177; in CA, (408) 492-1440. **Circle No. 393**

Schematic-Capture Tool For Macintosh

- *Compatible with EDA tools from major CAE vendors*
- *Provides 2-way link to Macintosh productivity tools*

McLogic is a schematic-capture package that runs on Macintosh computers. The program is compatible with EDA (electronic design auto-

Block Diagram Editor windows showing hierarchy of V.32bis modem



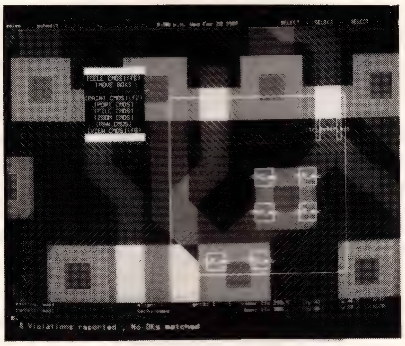
NOW SAVE HUNDREDS OF HOURS IN DSP AND COMMUNICATIONS DESIGN TIME.

mation) simulators, timing analyzers, and layout tools from major CAE vendors, as well as with Macintosh word processors and desktop publishing systems. You can transfer device libraries from host EDA systems directly into McLogic. You can also make the information contained in a schematic available to the productivity tools that run on the Macintosh. $2995.

Bobcat Systems, 900 W Valley Rd, Suite 204, Wayne, PA 19087. Phone (215) 975-0690.
Circle No. 394

VLSI-Design Checker

- *Accepts design files in CIF and GDS formats*
- *Checks IC mask-layer violations against your design rules*


8 Violations reported , No DKs matched

ChipDRC is the first offering in the vendor's ChipChecker product line, which consists of software to verify VLSI physical layout before final submission of an IC design to a fabrication house. The software runs on Sun workstations and 80386-based PCs. ChipDRC accepts design files in both CIF and GDS formats and generates a design-rule table from the engineer's own design rules. The program then uses both hierarchical and incremental checking to detect IC mask-layer violations of the design rules. An interactive mode allows you to check selected portions of your design while you are still in the layout editor. In batch mode, the program checks the entire chip design at high speed. PC version, $15,000; Sun-3 version, $19,500; Sun-4 and SPARCstation versions, $29,500.

Phase Three Logic Inc, 1600 NW 167th Pl, Beaverton, OR 97006. Phone (503) 645-0313. FAX (503) 645-0207. **Circle No. 395**

Development Aid For Windows Applications

- *Provides high-level language for defining windows*
- *Built-in functions handle memory-management problems*

KnowledgePro (Windows) is a tool for developing applications software that will run under Microsoft's Windows. The tool consists of a multiple-document editor for defin-

Text continued on pg 198

NOT TO MENTION YOUR SANITY.

Because the Signal Processing WorkSystem™ automatically converts designs into error-free simulation code, you spend your time designing systems, not debugging programs.

For example, working with SPW™ the design, simulation and analysis of the V.32bis modem shown here took one-fifth the time of conventional development techniques with hand coding. Plus SPW's full documentation allows quick and easy design enhancement.

SPW is the only complete, graphical software for all phases of DSP and communications product design, simulation and implementation. And now with its expanded Communications Library of more than 200 function blocks, SPW's range of design capabilities is broader than ever.

Arrange for a video demonstration of SPW by calling 415-574-5800.

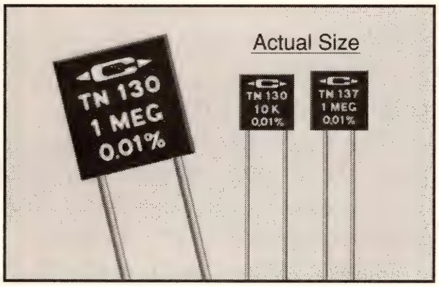
See how much it can do for your designs. And your sanity.

COMDISCO®
SYSTEMS, INC
415-574-5800

CIRCLE NO. 18

Type TN Lab Grade Low TC Precision Resistors

New

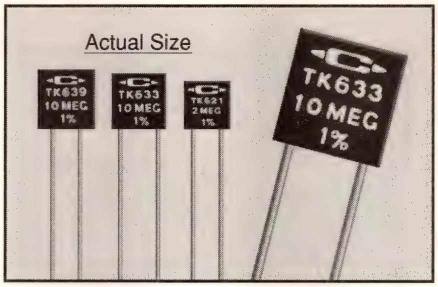


1 K to 1 Meg, Tolerance to ±0.01%
Low TC to 5 ppm/°C, 0°C to 70°C

- **Non-Inductive Design**
- Tolerance of ±0.01%, ±0.025%, ±0.05%, ±0.1%, ±0.25%, ±0.50% or ±1%
- Low TC of 5, 10 or 20 ppm/°C, 0 to 70°C
- Space Efficient Radial-Lead Design

For Type TN data, circle number 101

Type TK Low TC Precision Radial-Lead Film Resistors

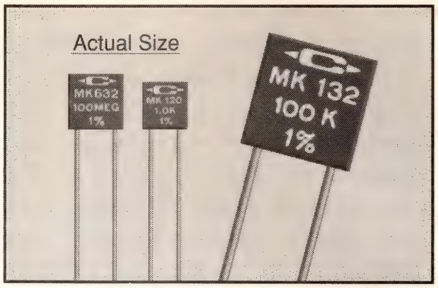


Low TC to 5 ppm/°C, -55°C to 125°C

- **Non-Inductive Design**
- Resistance Range 1 Kohm to 10 Meg
- TC of 5, 10 or 20 ppm/°C, -55 to 125°C
- Tolerance of ±1% (available to ±0.05%)
- Space Efficient Radial-Lead Design

For Type TK data, circle number 102

Type MK Precision Power Radial-Lead Film Resistors



0.50 Watt (CK05), 0.75 Watt (CK06)

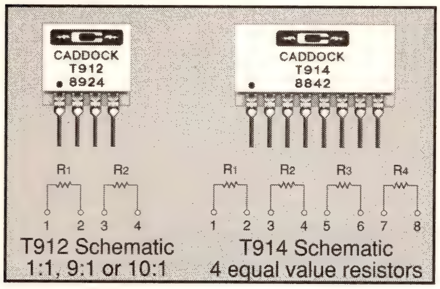
- **Non-Inductive Design**
- Resistance Range 1 Ω to 100 Meg
- TC as low as 50 ppm/°C, -15°C to 105°C
- Tolerance of ±1% (available to ±0.1%)
- Space Efficient Radial-Lead Design

For Type MK data, circle number 103

CADDOCK® Resistor Technology

Precision and Ultra Precision Resistors and Resistor Networks with a 25 year record for solving problems across the board!

Type T912 and Type T914 Precision Resistor Networks



T912 Schematic
1:1, 9:1 or 10:1

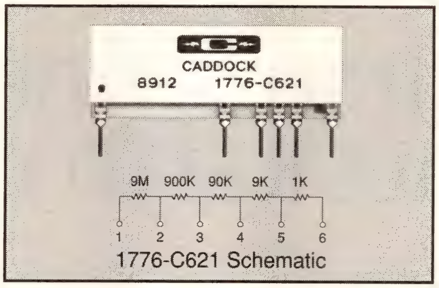
T914 Schematic
4 equal value resistors

Ultra Precise Ratios to 0.01%

- 14 Standard Resistance Values from 1 Kohm to 1 Meg (Custom to 2 Meg)
- Ratio Tolerance from 0.01% to 0.1%
- Ratio TC of 2, 5 or 10 ppm/°C, 0 to 70°C
- Custom ratios available, 1:1 to 250:1

For Type T912/T914 data, circle 104

Type 1776 Precision Decade Voltage Dividers



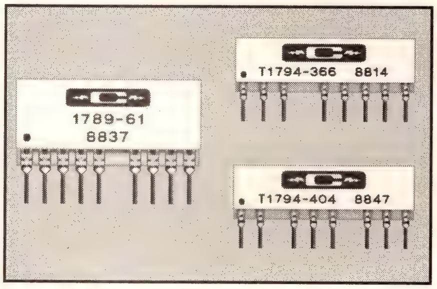
1776-C621 Schematic

Voltage Division 10:1 to 10,000:1

- Ratio Tolerance 0.02%, 0.05%, 0.1%, 0.25% or 0.5%
- Ratio TC of 5, 10, 25 or 50 ppm/°C, from 0°C to 70°C
- Select from 39 Different Models
- Voltage Rating to 1,200 Volts

For Type 1776 data, circle number 105

Custom Precision and Ultra-Precision SIP Networks



Ratio Tolerance to 0.01%

- Resistance Range 0.5 ohm to 50 Meg
- Abs. Tolerance from ±0.025% to ±1%
- Ratio Tolerance from 0.01% to 1%
- Abs. TC of 15 ppm, 25 ppm, 50 ppm or 80 ppm/°C, from 0°C to 70°C
- Ratio TC of 5 ppm, 10 ppm, 25 ppm or 50 ppm/°C, from 0°C to 70°C

For Custom data, circle number 106

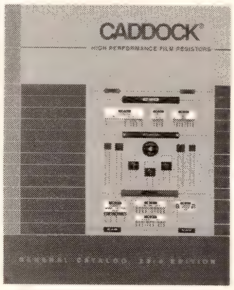
More high performance resistor products from

CADDOCK
ELECTRONICS, INCORPORATED

These products are manufactured with Caddock's exclusive Micronox® or Tetrinox® Resistance Film Technologies. For your copy of the Caddock General Catalog call or write:

Applications Engineering
Caddock Electronics, Inc.
1717 Chicago Avenue
Riverside, California 92507
(714) 788-1700

The Caddock General Catalog includes specifications on over 200 models of high performance resistor products.



© 1989 Caddock Electronics, Inc. L124.109

TOOLS FOR YOUR TRADE

New Electronics Titles from McGraw-Hill

SURFACE MOUNT TECHNOLOGY
3rd EDITION
ELECTRONICS ENGINEERS' HANDBOOK
DONALD G. FINK
DONALD CHRISTIANSEN
CMOS/TTL DIGITAL SYSTEMS DESIGN
JAMES BUCHANAN
MERRILL SKOLNIK
RADAR HANDBOOK
SECOND EDITION
DIGITAL BUS HANDBOOK
Joseph Di Giacomo
Television and Audio Handbook
OWEN J. McATEER
ELECTROSTATIC DISCHARGE CONTROL
SWITCHMODE POWER SUPPLY HANDBOOK
KEITH BILLINGS
SEMICONDUCTOR DEVICE MODELING WITH SPICE
PRINTED CIRCUITS HANDBOOK
COOMBS
THIRD EDITION
DESIGNING WITH FIELD-EFFECT TRANSISTORS
SECOND EDITION
SILICONIX INC.
REVISED BY ED OXNER

AVAILABLE NOW AT THESE FINE STORES

CALIFORNIA

Scholar's Bookstore
El Segundo, CA 90245
(213) 322-3161

OPAMP Technical Books
Los Angeles, CA 90038
(213) 464-4322

Stacey's Bookstore
Palo Alto, CA 94301
(415) 326-0681

Stanford Bookstore Palo Alto
Palo Alto, CA 94301
(415) 327-3680

San Diego Technical Books
San Diego, CA 92111
(800) 346-0071

Stacey's Bookstore
San Francisco, CA 94105
(415) 421-4687
FAX (415) 777-5017

Computer Literacy
San Jose, CA 95131
(408) 435-1118

Stanford Bookstore
Stanford, CA 94305
(415) 329-1217

Computer Literacy
Sunnyvale, CA 94086
(408) 730-9955

B. Dalton Bookseller
Torrance, CA 90503
(213) 370-5735

COLORADO

Auraria Book Center
Denver, CO 80204
(303) 571-0265

Tattered Cover Book Store
Denver, CO 80206
(303) 322-7727
(800) 833-5327

R & R Technical
Littleton, CO 80160
(303) 794-4518

United TechBook Company
Longmont, CO 80501
(303) 651-3184
(800) 247-4808

D.C.

B. Dalton Bookseller
1776 K Street, N.W.
Washington, DC 20006

Reiter's Scientific
Washington, DC 20006
(202) 223-3327

FLORIDA

Bookstop
Miami, FL 33156
(305) 598-7292

GEORGIA

Engineers Bookstore
Atlanta, GA 30313
(404) 892-1669

Oxford Bookstore
Atlanta, GA 30305
(404) 262-3333

ILLINOIS

Kroch's & Brentano's
Chicago, IL 60603
(312) 332-7500
Outside Chicago
(800) 833-BOOK
FAX (312) 332-6074

MARYLAND

Maryland Book Exchange
College Park, MD 20740
(301) 927-2510

MASSACHUSETTS

Boston University Bookstore
Boston, MA 02215
(617) 236-7415

B. Dalton Bookseller
Braintree, MA 02184
(617) 848-9542

SoftPro
Burlington, MA 01803
(617) 273-2919

M I T Coop
Cambridge, MA 02142
(617) 491-4230
FAX (617) 621-0856

Quantum Books
Cambridge, MA 02139
(617) 494-5042
FAX (617) 577-7282

B. Dalton Bookseller
Framingham, MA 01701
(508) 872-1264

NEW JERSEY

McGraw-Hill Bookstore
Hightstown, NJ 08520
(609) 426-5749

Princeton University Store
Princeton, NJ 08540
(609) 921-8500

NEW YORK

Barnes & Noble
105 Fifth Avenue
New York, NY 10003

McGraw-Hill Bookstore
New York, NY 10020
(212) 512-4100

Waldenbooks
57 Broadway
New York, NY 10006

Total Information Inc.
Rochester, NY 14613
(716) 254-0621
(800) 876-4636
FAX (716) 254-0153

OHIO

University Bookstore
Cincinnati, OH 45221
(513) 556-1292

Borders Book Shop
Columbus, OH 43220
(614) 451-2292

OREGON

Powell's Technical
Portland, OR 97209
(503) 228-3906
(800) 225-6911

TENNESSEE

Davis-Kidd Booksellers
Nashville, TN 37215
(615) 385-2645

TEXAS

Bookstop
Austin, TX 78752
(512) 453-7297

University Co-op
Austin, TX 78705
(512) 476-7211

Bookstop
Dallas, TX 75230
(214) 363-5744

Taylor's Technical Books
Dallas, TX 75240
(214) 239-TECH

Bookstop
Houston, TX 77098
(713) 529-2345

Brown Book Shop
Houston, TX 77002
(713) 652-3937
FAX (713) 652-1514

Bookstop
San Antonio, TX 78230
(512) 697-0588

WASHINGTON

Tower Books
Bellevue, WA 98004
(206) 451-1110

Elliott Bay Professional
Seattle, WA 98104
(206) 624-6658

University Bookstore
Seattle, WA 98105
(206) 634-3400

WISCONSIN

Harry W. Schwartz Bookshop
Milwaukee, WI 53202
(414) 274-6400
Outside Milwaukee
(800) 552-READ
FAX (414) 276-4577

Visit us at Electro/90 in Boston—
Booth #1312

Your Computer Series Publisher

McGraw-Hill, Inc.
Professional & Reference Division

In Canada, please contact McGraw-Hill Ryerson at (416) 321-7610.

CIRCLE NO. 109

ing your windows, hypertext functions that let you link them, a hypertext on-line help system that describes all available KnowledgePro functions, and debugging functions that let you trace or single-step your application. The package has extensive list-handling facilities as well as string-handling, file-searching, and indexing functions. A combination of object-oriented and artificial-intelligence techniques automatically handles all memory-management requirements and makes it simple to design multiple windows that include icons of all kinds, including radio buttons to initiate specific actions in the application. From any window that you've created, you can run external Windows or DOS programs; a dynamic-data-exchange (DDE) feature allows you to take control of other Windows programs such as Excel or Word. $695.

Knowledge Garden Inc, 473A Malden Bridge Rd, Nassau, NY 12123. Phone (518) 766-3000. FAX (518) 766-3003. **Circle No. 396**

Telecommunications Software

- *Works with all versions of OS/2*
- *Comes with file-transfer and terminal-emulation utilities*

PC/TCP is an implementation of the industry standard TCP/IP (Transmission Control Protocol/Internet Protocol), which allows different types of computers, running different operating systems, to communicate with each other. PC/TCP allows 80286- and 80386-based computers running OS/2 to communicate with other PCs as well as with minicomputers and mainframes that run under operating systems such as Unix, IBM's VM and MVS, and DEC's VAX/VMS. The software works with all versions of OS/2, including IBM's Extended Edition. The software uses Presentation Manager for multitasking and windowing, and comes with a comprehensive set of TCP/IP utilities. These include FTP (File Transfer Protocol) client and server; Telnet client and server, which allows users to log onto remote hosts (includes VT102 and IBM 3270 emulation); remote command execution; conversational communication; E-mail facilities; and network information and debugging utilities such as *netstat*, *ping*, *finger*, and *whois*. $575.

FTP Software Inc, 26 Princess St, Wakefield, MA 01880. Phone (617) 246-0900. FAX (617) 246-0901. **Circle No. 397**

Announcing the new
PADS-PAK

CAD Software, Inc., developers of the world's best-selling Printed Circuit Board design software, is now offering PADS-PCB, PADS-AUTOROUTE, and PADS-PLOT as a bundled package, called PADS-PAK. Priced at **$1,495.00,** the system offers a savings of over 25%.

- 250 IC design capability
- Automatic gate and pin swap
- Group move, copy and rotate
- Complete design rule checking
- SMT design with predefined via arrays
- Buried and micro vias
- Fine line and analog routing
- Orthogonal-maze, memory and power/ground routers
- Full Gerber artwork generation . . . *and more!*

Call today for your local Authorized CAD Software Dealer and a NO-COST Evaluation Package. Most major credit cards accepted. **Ask about our *new* Leasing Plan.**

30 DAY MONEY BACK GUARANTEE

CAD
Software, Inc.
119 Russell Street, Suite #6
Littleton, MA 01460

Call Today

Inside MA: (508) 486-8929
Outside MA: (800) 255-7814

CIRCLE NO. 20

"A SINGLE AD IN **EDN NEWS EDITION** GENERATED AN INQUIRY LEADING TO A $2 MILLION OPPORTUNITY!"

John Poturny, President
Poturny & Associates
Northridge, CA

Fred Silver, Director of Marketing
Rantec
Chatsworth, CA

Advertising results. Agencies want them. Clients need them.

"When I was on the client side, I demanded sales results from my advertising dollars," says John Poturny, President of Poturny & Associates. "Today I'm on the agency side, and I expect the same for my clients — advertising that generates sales."

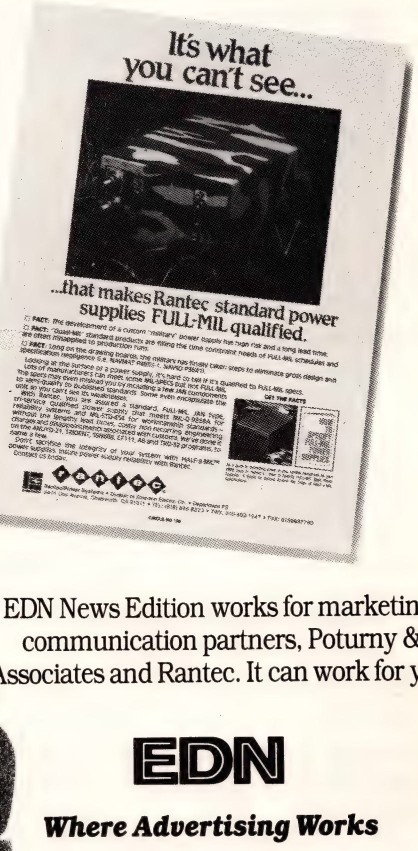
Advertising results. A publication must provide them.

"After running ads in EDN News Edition, our phones ring and proposal activity soars immediately for our military power supplies," says Fred Silver, Director of Marketing at Rantec, a division of Emerson Electric.

Advertising results. For Poturny & Associates and Rantec, EDN News Edition gets them.

"We traced prototype orders worth $2 million in sales to a lead generated by our ad in EDN News Edition," said Silver.

Both Silver and Poturny agree about the power of EDN News Edition, "it gets results."



It's what you can't see...

...that makes Rantec standard power supplies FULL-MIL qualified.

EDN News Edition works for marketing communication partners, Poturny & Associates and Rantec. It can work for you.

EDN

Where Advertising Works

NEW PRODUCTS

COMPUTERS & PERIPHERALS

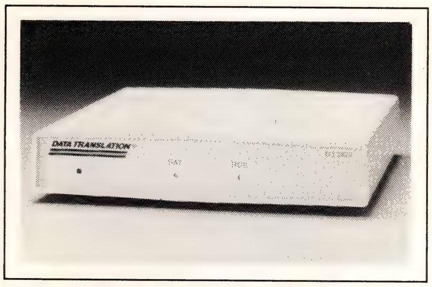
Z8 Development System

- *Contains two Z8 μCs and 16k bytes of RAM*
- *Can define any of 32 I/O lines on user's Z8 microcomputer*

The Z8DM development system for Zilog's Z8 microcomputer is a stand-alone board that contains two Z8 μCs. One μC controls the board's output and input ports and its memory and status lines. The other Z8 is free for user definition. Using a dedicated connector, users can define any of the 32 I/O lines on the Z8. Standard configuration includes 16k bytes of static RAM and an on-board 2716-, 2732-, or 2764-compatible EPROM socket. The system lets you set 4096 hardware breakpoints via address comparison. A monitor provides debugging and register manipulation as well as file uploading and downloading from a host. An adapter is also included for Z8600 μC emulation. NMOS version, $795; CMOS upgrade kit, $95.

IAM Inc, Box 2545, Fair Oaks, CA 95628. Phone (916) 961-8082.

Circle No. 379



Video Encoder And Decoder

- *Converts NTSC or PAL formats to RS-170 or CCIR RGB*
- *Transmits images from frame grabbers on different computers*

The DT2879 is a stand-alone video encoder and decoder box. Two versions of the board decode input signals with NTSC or PAL formats and encode them to RS-170 RGB or CCIR RGB output signals, respectively. The box also performs the reverse operation. It permits direct transmission of digital video images from frame grabbers on different computers such as Nubus, the Micro Channel Architecture bus, ISA bus or VMEbus boards. When decoding NTSC or PAL signals to RGB signals, the DT2879 can accept signals from composite video cameras. The NTSC version operates at 60 Hz and has an external power supply that uses 115V ac. The PAL version operates at 50 Hz and comes with either a 220 or 240V ac supply. $995.

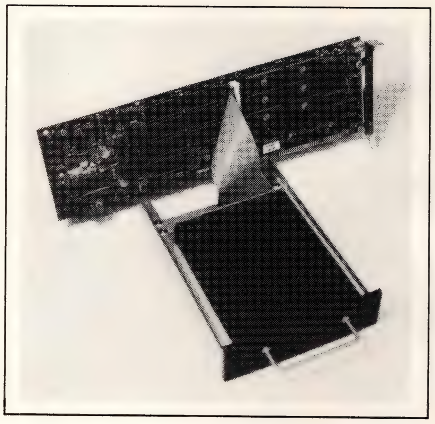
Data Translation, 100 Locke Dr, Marlboro, MA 01752. Phone (508) 481-3700. TLX 951646. FAX (508) 481-8620.

Circle No. 380

Solid-State Disk Drive

- *Operates as 1.2M-byte EPROM or 640k-byte SRAM*
- *Memory module resides in $5^1/_4$-in. disk-drive bay*

The Mod/Edisk solid-state disk-drive system plugs into an 8-bit ISA bus. The system's memory module resides in an industrial aluminum box that slides into a half-height, $5^1/_4$-in. disk-drive bay. The module attaches to the plug-in card via a ribbon cable. The system operates as either a 1.2M-byte rewritable EPROM or a 640k-byte battery-backed static RAM (SRAM). An EPROM version can incrementally add, delete, or change files on the disk-drive system. The EPROM version also contains a nonvolatile 31k-byte RAM disk, which can store rapidly changing data or configuration files. EPROM version, $975; SRAM version, $1275.



Wiztech Computer, Box 121, Lynden, WA 98264. Phone (604) 852-1155. FAX (604) 852-2894.

Circle No. 381

WHEN YOUR REPUTATION'S ON THE LINE.

For superior battery performance, reliable enough to risk your reputation on, specify Rayovac.

For quality in the long run, consider our 844 Computer Clock Battery. Its unique architecture delivers economical long life and safe, reliable operation.

Our Lifex Lithium Coin Cells offer a shelf life ten times longer than conventional crimp seal batteries. With greater capacity retention and superior performance. They're available in a variety of tab and pin configurations.

For reliability in harsh environments, consider our Lifex FB batteries. Encapsulated cell technology allows them to withstand humidity, thermal shock and temperatures from -40ºC to +100ºC.

To set your ideas into motion, call your distributor. And tap into the power of innovation at Rayovac.

RAYOVAC®

The power of innovation.

Allied Electronics
1 800 433-5700

Norvell Electronics
1 214 233-0020

Applied Power
1 313 227-3604
1 800 624-5496

GCI
1 609 768-6767

Sterling/Image Electronics
1 714 259-0900
1 800 822-5514

CIRCLE NO. 113

© 1989 Rayovac Corporation

Mac-To-IBM Connection

- *Connects to coax, SDLC, and token-ring networks*
- *Macintoshes on EtherTalk can use IBM 3270 data*

The MacFrame Series of products provides Macintosh computers with a connection to IBM 3270 mainframe computers. The products provide Macintosh users on EtherTalk, TokenTalk, or LocalTalk LANs with a means of communicating with coax, SDLC (synchronous data link control), or token-ring IBM networks. The products consist of a plug-in card for the Macintosh computer and software. The MacMainFrame SDLC workstation card connects to a synchronous modem that provides access to as many as eight simultaneous mainframe sessions via an SDLC network. The MacMainFrame token-ring workstation card transmits and receives data with a token-ring network using IBM 3278/3279 terminal emulation. The MacMainFrame coax gateway card gives Macintosh users access to as many as five mainframe sessions via a coax network. SDLC workstation, $1295; token-ring workstation, $1295; coax gateway, $2495.

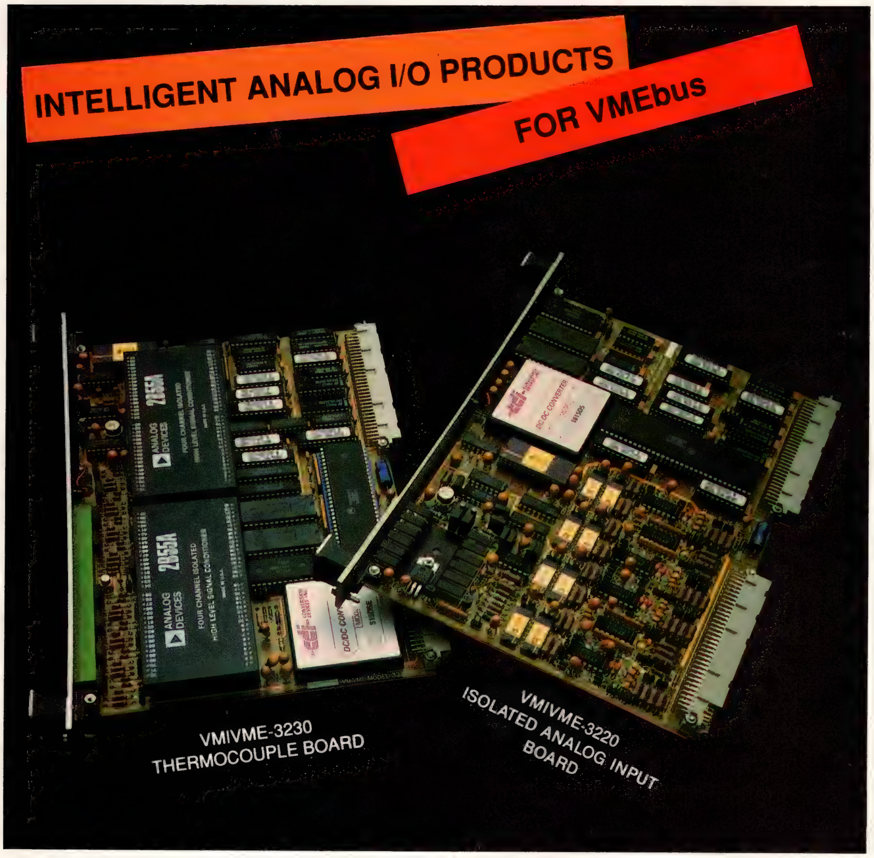
Avatar Corp, 65 South St, Hopkinton, MA 01748. Phone (508) 435-3000. FAX (508) 435-2470.

Circle No. 382

Ethernet Switch

- *Separate packet routers feed crosspoint switch*
- *Provides 100% packet filtering and forwarding*

The EtherSwitch is a multiport switching system for Ethernet networks; it consists of a central crosspoint matrix switch that attaches to independent packet-switching routers for each port. The switch permits more than one packet to travel on the network without col-



VMIC's ANALOG I/O PRODUCTS JUST GOT SMARTER!

Our INTELLIGENT ANALOG I/O PRODUCTS feature a 68000 CPU that supports board and system level calibration and processes all inputs into user-specified data formats and engineering units. Each board features nonvolatile storage to eliminate offset and gain potentiometers, dual port data registers, 13-bit digitizing of eight differential input channels, and accepts multiple input types simultaneously. And, both boards are fully compatible with GE Fanuc Series 90/70 PLC.

Our intelligent ISOLATED ANALOG INPUT BOARD provides excitation, lead compensation and linearization for RTD inputs, accepts full and half bridge strain gage inputs, and processes a wide variety of general purpose analog signals.

The THERMOCOUPLE BOARD features fully isolated inputs, and provides linearization and cold junction compensation for 11 thermocouple types. A high-level version can be used for current loop inputs.

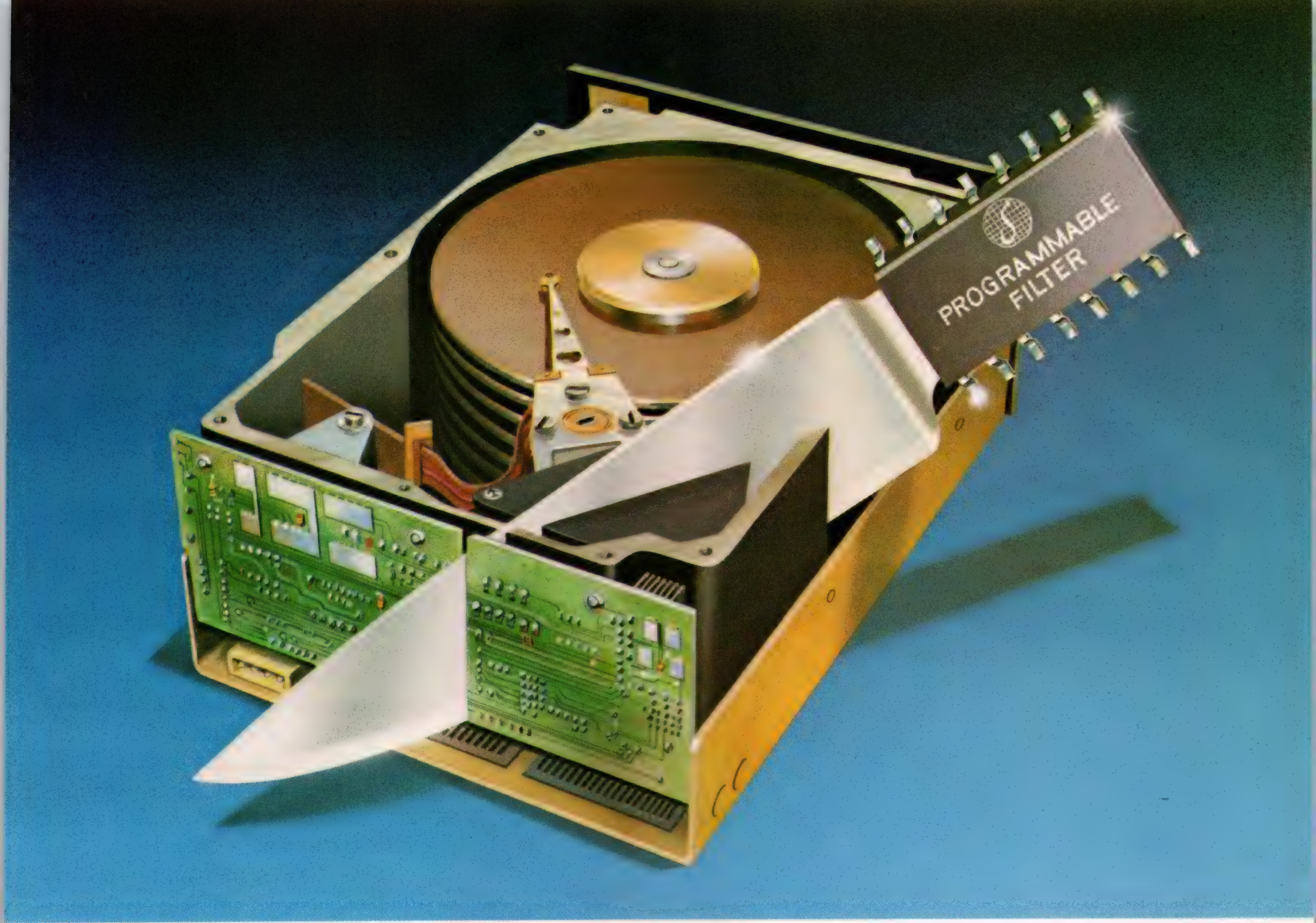
When your project requires intelligent processing on VMEbus, call VMIC.

VME
VMIC®

VME MICROSYSTEMS INTERNATIONAL CORPORATION
12090 South Memorial Parkway, Huntsville, Alabama 35803-3308
(205) 880-0444 FAX: (205) 882-0859 **1-800-322-3616 EXT. 2189**

INTERNATIONAL DISTRIBUTORS: UNITED KINGDOM, DIAMOND POINT INTL. (44) (634) 722390, FAX (44) (634) 722398; INDIA, DIAMOND POINT INTL. 812-607567; CANADA, TRACAN ELECTRONICS CORP., (416) 625-7752, FAX (416) 625-4986; AUSTRALIA, VME SYSTEMS PTY LTD. (VICTORIA) (03) 890-0890, FAX (03) 890-0644 (SYDNEY) (02) 956-3814, FAX (02) 439-7765

CIRCLE NO. 19



Cut your board space and design time...

With the World's First High-Frequency Programmable Filter

A new high-frequency Programmable Filter Chip from Silicon Systems is a significant development for disk drive designers employing constant-density-recording techniques.

The SSI 32F8010 is the latest technological breakthrough in filter design since the introduction of switched capacitor filters. This electronically-tuned filter greatly simplifies the designer's task. It obsoletes do-it-yourself passive-filter design, eliminates a variety of components, cuts down on board space, and improves system performance. It is an off-the-shelf solution for what has previously been a difficult engineering-intensive part of hard-disk-drive design.

This low-pass filter allows the user to continuously program the channel bandwidth from 5-13 MHz while changing data rate for constant-density recording. Additionally, pulse equalization/pulse slimming levels from 0 to 6dB are programmable. It does it all with no external passive components.

But the new programmable filter is not restricted to disk drive applications. It is equally useful for a large variety of signal filtering and conditioning circuitry in telecom, video, and audio applications. It is big news for any systems engineer who is seeking a better filter design solution.

CALL NOW!

(714) 731-7110, Ext. 3575

For more information on this new breakthrough in filter design, contact Silicon Systems, your local representative, or distributor today.

Silicon Systems, Inc.
14351 Myford Road, Tustin, CA 92680
Ph: (714) 731-7110, FAX: (714) 669-8814
European Hdq. U.K. Ph: (44) 7983-2331
European Hdq. U.K. FAX: (44) 7983-2117

Circle 36 For Product Information

silicon systems®

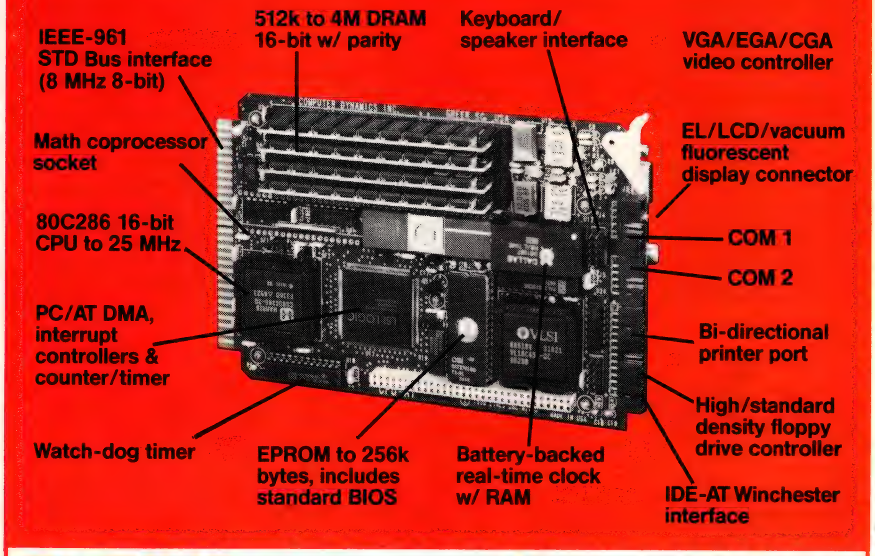
CIRCLE NO. 30

liding with other packets. A 10-port switch permits five simultaneous conversations, and a 20-port switch permits 10. The switch provides 100% packet filtering and forwarding, and each port has buffer storage for as many as 256 packets (1500 bytes). Typical port-to-port routing delay is 40 µsec. The packet routers verify a packet's destination by monitoring the 6-byte destination address in the header and forwarding the packet on the fly to the appropriate port. A dynamic routing table facilitates on-the-fly packet routing by reading the source data in the header. The switch updates the table for new sources and eliminates inactive ones. $4995 to $9995.

Kalpana Inc, 550 Division St, Campbell, CA 95008. Phone (408) 378-3645. FAX (408) 370-2456.

Circle No. 383

The No-Compromise PC/AT Designed for Embedded Control



The CPU-AT gives you everything on one module:

On-Board Power
80C286 CPU to 25 MHz and 4 Mbytes DRAM
All the PC/AT functions—100% compatible!

"Go Anywhere" Size and Reliability
More power than a desktop AT, in less than 10% of the space
0 to 70°C operation and low power requirements

Flat Panel Display Drivers + VGA
Directly drives popular graphics displays: LCD, EL, plasma, vacuum fluorescent; CRTs, too

ROM or Disk-Based Applications Fully Supported
ROMing your code is a snap with our exclusive ROMing utilities

Expandability through the STD Bus
Use the CPU-AT with any STD Bus I/O

Price: $995 or $1995 with VGA and disk interfaces

Call for your FREE CPU-AT brochure, "ROMing" software demo diskette, and 1990 STD Bus System Development Guide.

Member STDMG
PC/AT is a trademark of IBM Corp.

Computer DYNAMICS
COMPUTER DYNAMICS SALES
107 S. MAIN ST., GREER, SC 29650
(803) 877-8700 FAX (803) 879-2030

Video-Graphics Board

- *Captures NTSC or RGB analog signals*
- *Displays 512×512×16 pixels with as many as 32,768 colors*

The Illuminator-16/MC is a video-graphics board for IBM's PS/2 computers. The Micro Channel board captures and digitizes NTSC or RGB analog inputs in real time. It digitizes the signals with 5-bit/color resolution and displays 32,768 colors. The board can display 512×512×16 pixels, which are expandable to 1024×1024×16 pixels with a 2M-byte frame-buffer option. Subdividing the frame buffer creates multiple pages for image comparison or animation applications. The board operates with both interlaced and noninterlaced monitors. A hot-key utility program provides access to video effects when running Truevision's Targa graphics software. In addition, the board can overlay VGA graphics on live video, frame-buffer contents on live video, VGA graphics on the frame buffer, and frame-buffer contents on VGA graphics. $1795.

Matrox Electronic Systems Ltd, 1055 St Regis Blvd, Dorval, Que, Canada H9P 2T4. Phone (514) 685-2630. FAX (514) 685-2853.

Circle No. 384

Accelerator Board

- *Contains a socket for Intel or Weitek coprocessor*
- *Runs on 80386 µP*

The Number Smasher-386 is an accelerator board for the ISA bus, which replaces an 80286 µP with either a 20- or 25-MHz 80386 µP. The board contains sockets to add 1M, 2M, 4M, or 8M bytes of mem-

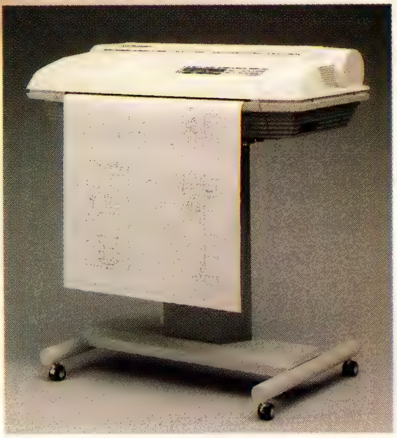
Recording the Past…
…Plotting the Future

Our reputation precedes us! From 5 subsidiaries and 35 distributors in more than 40 countries worldwide, thousands of customers purchased more in 1989 than ever before. And they were able to choose new products from an ever-expanding array of plotters, penless plotters, digitizers, recorders and supplies.

The Graphtec reputation is one of building products that work well and last a long time. We earned that reputation the hard way, by delivering over 40 years of the best innovation, support, and after-sales service in the industry.

One of the finest examples of Graphtec innovation is incorporated into our new TM1110/1210 series of thermal plotters. These plotters are unique thanks to the world's first single-substrate, large-format thermal head. The single head ensures a uniform, high-quality printout with superb 406 dpi (16 dots/mm) resolution.

Hard copies can be made on three types of media: regular, thermal transfer and clear film. Also, RS-232C and Centronics interfaces come standard, as do GP-GL and HP-GL™ command sets.



TM1110 A1-size Thermal Plotter

GRAPHTEC

GRAPHTEC CORPORATION Mita 43rd Mori Bldg., 13-16, Mita 3-chome, Minato-ku, Tokyo 108, Japan Tel: (03) 453-0511 Telex: 02422687 (GRAPH-J)

U.S.A.: American Graphtec, Inc. Tel:(714)261-7568 (800)654-7568 Fax:(714)833-7568

Europe: Graphtec Europe GmbH Tel:(040)511-5059 Telex:2165630 (GTEC D)

Australia: Southern Graphtec Pty. Ltd. Tel:(02)748-4888 Fax:(02)748-4882

United Kingdom: Graphtec (UK) Ltd. Tel:(0270)625-115 Fax:(0270)626-733

*HP-GL is a trademark of the Hewlett-Packard Company.

CIRCLE NO. 114

ory. It also has a 121-pin socket that accepts an Intel 80387, Cyrix FasMath 83D87, or Weitek 3167 coprocessor. You can install a cache memory module in an additional socket. The board operates as an asynchronous emulator with shadow memory and is compatible with zero- or one-wait-state 80286-based systems operating between 6 and 12 MHz. The board runs real and protected-mode software for the 80286 µP such as AutoCAD, Microsoft's Windows, Lotus 1-2-3, Microsoft Word, DOS, Xenix, and OS/2. It also runs protected-mode programs for the 80386 such as Unix System V, SCO Xenix, Windows-386, and DESQview-386. 20-MHz version, $895; 25-MHz version, $1095.

Microway, Box 79, Kingston, MA 02364. Phone (508) 746-7341. FAX (508) 746-4678.
Circle No. 385

Real-Time Unix Computer

- *Average response time of 100 µsec for an interrupt*
- *Uses from R3000 and R3010 RISC CPUs*

The Series 8000 family of computers runs on the company's real-time Unix operating system, RTU version 6.0. Models 8300 and 8400 have six VMEbus slots. They use a 9U VMEbus board with either one or two Mips (Sunnyvale, CA) R3000 and R3010 reduced-instruction-set-computer CPUs; they also have a 64k-byte instruction cache and a 64k-byte write-through data cache. An additional 256k-byte second-level cache sits between the data cache and a 64M-byte/sec memory bus. Another VMEbus board has a minimum of 8M bytes of memory (expandable to 64M bytes) with error-correction code. The Model 8500 provides as many as four dual CPU boards and as many as two memory boards. The systems work with an Intelligent Peripheral Interface level-2 848M-byte disk drive and an Ethernet-based terminal server. The systems respond to an interrupt on an average of 100 µsec. 8300, $55,900; 8400, $57,400; 8500, $93,500.

Concurrent Computer Corp, 106 Apple St, Tinton Falls, NJ 07724. Phone (800) 631-2154; in NJ, (201) 758-7000. **Circle No. 386**

S Bus-To-VMEbus Adapter

- *Has SPARCstation I card and 6U VMEbus board*
- *Operates as bus master on VMEbus*

The Model 466 S bus-to-VMEbus adapter has two plug-in boards—an S bus plug-in card for Sun's SPARCstation I and a 6U VMEbus board. The cards connect via a round EMI-shielded cable that can be 8 or 25 ft long. The adapter operates as a bus master on the VMEbus; it has access to as much as 4G bytes of global memory on the VMEbus using the A32:D32 protocol. In addition, the board can access the entire 64k-byte VME I/O space, which appears as a memory-mapped address in the Sun computer. Optional daughter cards attach to the VMEbus board and provide 32k, 128k, or 1M byte of dual-port memory as an alternate means of bus-to-bus communication. The adapter can handle all the VMEbus interrupts and manage the VMEbus system-control functions. As a system controller, it provides level 3 bus arbitration. $1995.

Bit 3 Computer Corp, 8120 Penn Ave S, Minneapolis, MN 55431. Phone (612) 881-6955. FAX (612) 881-9674. TLX 4997016.
Circle No. 387

Graphics Card

- *Provides resolution of 512×512 pixels for ISA bus*
- *Incorporates either a T414 or T800 Transputer*

The Harlequin G is an output video card for an IBM PC, PC/AT, or compatible computer. It provides 512×512-pixel resolution and displays a 262,144 color palette. The board uses either a 32-bit Inmos T414 or T800 Transputer along with 1M byte of dynamic RAM and two 256k-byte dual-ported image buffers. A rear-panel 48-way connector links the four Transputer 20M-bps channels to multi-Transputer networks. A B007 graphics support package written in Occam lets you operate with Microsoft or parallel Fortran, Turbo Pascal, or Microsoft or parallel C languages. £1695.

Quintek Ltd, Southfield House, 2 Southfield Rd, Westbury-on-Trym, Bristol BS9 3BH, UK. Phone (272) 628196. FAX (272) 628717.
Circle No. 388

STD Bus SBC

- *Provides all the functions of an IBM PC/AT*
- *Has 25-MHz 80C286 µP and 4M bytes of zero-wait-state DRAM*

The CPU-AT STD Bus single-board computer provides all the functions of an IBM PC/AT-compatible computer. The board contains a 25-MHz 80C286 µP, as much as 4M bytes of zero-wait-state dynamic RAM, 256k bytes of EPROM, two RS-232C ports, a parallel printer port, a floppy-disk controller, a hard-disk-drive interface, and a battery-backed real-time clock. The board is available for IBM CGA, EGA, VGA, or compatible displays. The board's display controllers plug into a CRT and directly drive LCDs, as well as plasma, electroluminescent, and vacuum fluorescent flat-panel displays. An LTD version comes without a display or disk controller for use in embedded control systems. The board comes with a licensed BIOS for running MS-DOS. DOS can boot and run on a floppy-or hard-disk drive as well as an onboard ROM disk. $995.

Computer Dynamics Sales, 107 S Main St, Greer, SC 29651. Phone (803) 877-8700. FAX (803) 879-2030. **Circle No. 389**

MIL-STD-1772 Certified & Qualified

If your next T/H-A/D design demands specified dynamic performance, relax. Micro Networks makes a complete

RELAX

family of Sampling A/D Converters with internal, user-transparent T/Hs. No "glue" logic required. Guaranteed specifications up to the Nyquist limit. Just plug in, power up and supply convert command. What could be simpler. To take your next DSP project from stressed out to designed in, call Micro Networks at (508) 852-5400. Or return the coupon.

Micro Networks' Sampling A/Ds are ideal for all wide-input bandwidth applications, especially DSP applications in industrial, military and aerospace programs.

Features

Easy-to-use.

Known performance.

FFT tested and specified for DSP applications.

Available with Environmental Stress Screening or Fully Compliant to MIL-STD-883, Method 5008.

12-Bit

MN6249
2MHz
Sampling Rate
68dB SNR
-72dB Harmonics & Spurious Noise

MN6774
100kHz
Sampling Rate
70dB SNR
-80dB Harmonics & Spurious Noise

16-Bit

MN6295
50kHz
Sampling Rate
84dB SNR
-88dB Harmonics & Spurious Noise

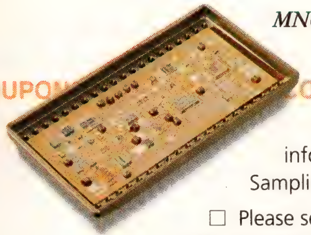
20-Bit

MN5420
320kHz
Sampling Rate
120dB Dynamic Range
16-Bit Floating Point Output

MICRO NETWORKS
324 Clark St., Worcester, MA 01606
Phone: (508) 852-5400 Fax: (508) 853-8296

PRECISELY THE ANSWER.

CIRCLE NO. 100



MN6249

COUPONCOUPONCOUPONCOUPON

☐ Please send me more information about Micro Networks Sampling A/D Converters.

☐ Please send me the Micro Networks 1990 Short Form Catalog.

☐ Please have an applications engineer call me.

Name ______________ Title ______________
Company ______________ M/S ______________
Address ______________ Phone ______________
City ______________ State ______ Zip ______________
My application is ______________

Is a Standardized Military Drawing product required? Yes ☐ No ☐

EDN051090

COUPONCOUPONCOUPONCOUPONCOUPON

Stepper Motor Drivers on the right track.

Speed and power in surface mount or through-hole packages.

Wooden train made by BRIO AB,
Sweden. © BRIO AB, Sweden 1990.
Protected by Patents and Regd.
Trade Marks internationally.

Switch to Ericsson and take advantage of the high-performance records we've been setting since 1982, when we introduced the first switched mode stepper motor driver IC.
Sit back and enjoy the speed and the power as you command more torque at higher speeds, thanks to our original constant-current chip architecture, now used – and copied – all over the world.
Jump on board and meet our team of single and dual drivers, with current ratings up to 1.8A, in low-cost Batwing DIP or the new Power PLCC package with heat-spreading lead frames.
And make a first class reservation with our microstepping chip set, with features to improve performance and cut hassle in your next robotic or instrumentation design.
Don't miss the Ericsson connection – send for our latest shortform product guide.

Our new Dual Channel Stepper Motor Driver PBL 3772 delivers more current at less power dissipation than two single channel devices.
Also available: the original PBL 3717 Chopper Driver and the pin-compatible PBL 3770A with 1.8A peak output, in DIP or power PLCC packages.
And the advanced chip set for micro-stepping, PBL 3771/PBM 3960.

ERICSSON

We're in the lead

Ericsson Components AB
S-164 81 Kista-Stockholm, Sweden.
Telephone +46 8 757 5000
Telefax +46 8 757 4776

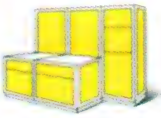
CIRCLE NO. 116

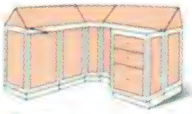
The last thing an enclosure should be is confining

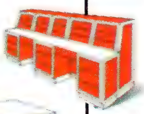
When you've engineered an innovative electronic system, it deserves better than to get packaged in a not-quite-perfect cabinet. That's why, in working to meet your enclosure requirements, Equipto Electronics believes that flexibility and versatility are no less important than reliability and quality.

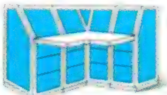
So how do we provide you with that flexibility?

First, by offering cabinets, consoles and work stations in several lines so extensive you can usually find exactly what you need. You can choose panels 19,″ 24″ or 30″ wide, up to 36″ deep with panel openings up to 84″ high. You can choose from hundreds of accessories in thousands of sizes. And you can choose enclosures especially engineered to provide maximum shielding effectiveness in meeting EMI/RFI, FCC, Military, TEMPEST and EMP requirements.









Color? Our 12 standard colors are available in any combination on any of our enclosures. Or, specify a color without extra charges or delay in delivery.

But, if we don't have what you need on hand, we don't expect you to compromise.

Call us and an experienced customer service representative will answer your questions. Or, contact our factory trained sales representative in your area. One of our design engineers can consult with you by phone or Fax, at no charge. And our factory engineering support is available to assist with any major project at your location.

We'll provide reproducible engineering drawings on request. And, if needed for evaluation—even for destructive testing—we'll send you a standard enclosure free, or a custom unit at a nominal charge.

We offer this extra level of service so you can get all the flexibility you need from a single source. And get it fast. The most popular choices from our extensive catalog can be shipped in 5 working days. And we promise anything you order from our catalog will ship within 5 weeks, assembled to your specifications at no extra charge, no surprises, damage free.

When Equipto Electronics started manufacturing enclosures nearly three decades ago, we made a commitment to the combination of quality products and quality service that helps you design and create without confinement.

Phone or Fax for our newest 304-page catalog, on a diskette or in the printed version, including extensive technical data and our Easy Order/Quote Form. Or, let us send you our Engineering Design Kit including catalog, EMI/RFI Technical Guide, Easy Order/Quote Form, corner and hardware samples and complete pricing information. Contact Equipto Electronics Corporation, 351 Woodlawn Avenue, Aurora, Illinois 60506-9988.

Phone now (708) 897-4691, or Fax (708) 897-5314.

Committed to Excellence Since 1960

EQUIPTO

***Electronics Corporation*®**

© Equipto Electronics Corporation 1990

See our catalog pages C-1040 through C-1052

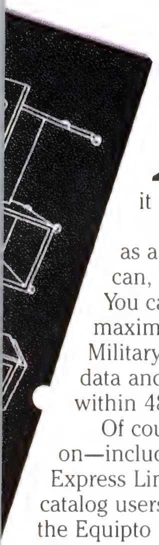
eem/electronic engineers master

Circle No. 25 On Reader Service Card

After yea
our cabinets, you can no

©Equipto Electronics Corporation, 1990

f putting your electronics in
ok at our cabinets electronically



Now you can get the Equipto Electronics catalog on a free floppy diskette. It includes all the modular electronic cabinets and computer furniture featured in our 304-page print version. And it runs on any IBM© compatible PC.

That makes it easier than ever to use Equipto Electronics as a design resource. With the help of on-screen prompts, you can, in effect, design your enclosure from thousands of options. You can even select enclosures especially engineered to provide maximum shielding effectiveness in meeting EMI/RFI, FCC, Military, TEMPEST and EMP requirements. Then, just print out the data and Fax it to us. We'll respond with your quote, usually within 48 hours.

Of course, all the extra services that Equipto customers count on—including customer service reps, engineering consultation or Express Line 5-Day Shipping—are readily available to computer catalog users. In fact, about the only thing that has changed about the Equipto Electronics catalog is that now you can thumb through it electronically.

It all adds up to commitment. A commitment by Equipto Electronics Corporation to provide the combination of quality products and quality service that helps you create the right enclosure for your project.

For your FREE copy of the Equipto Electronics diskette catalog—phone, FAX or write us today.

Equipto Electronics Corporation
351 Woodlawn Avenue
Aurora, Illinois 60506-9988
Phone (708) 897-4691
Fax (708) 897-5314

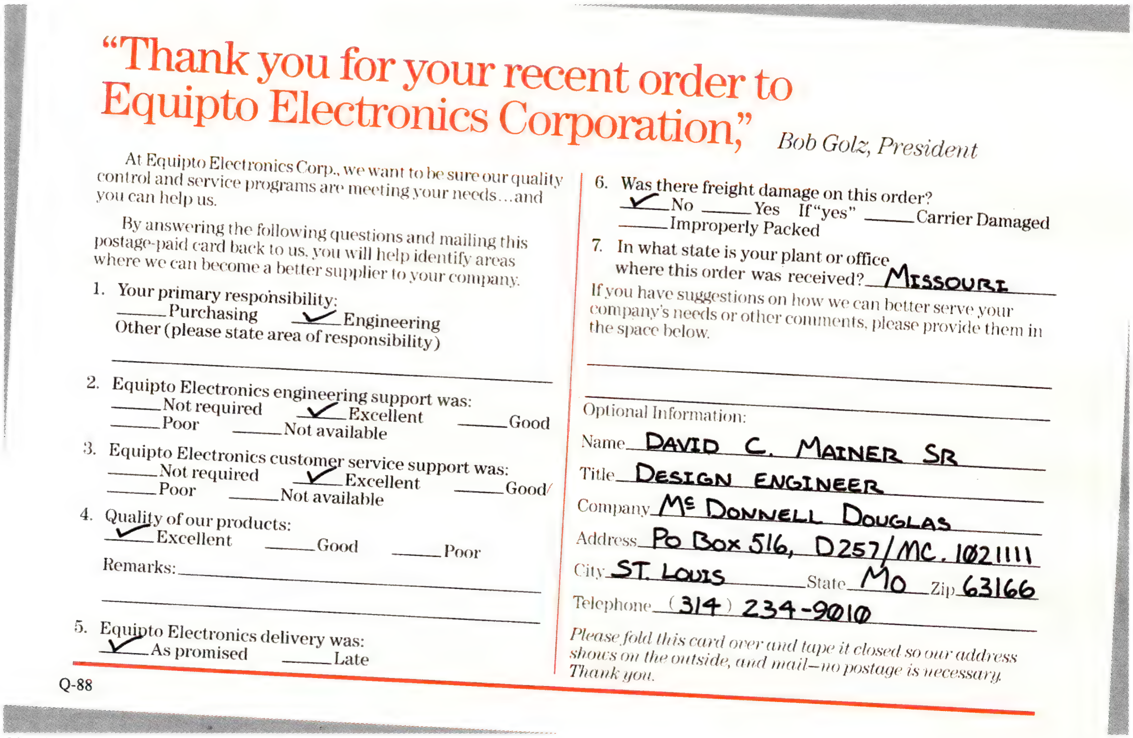
Committed to Excellence Since 1960

EQUIPTO
***Electronics Corporation*®**

See our catalog pages C-1040 through C-1052
eem/electronic engineers master

Circle No. 25 On Reader Service Card

When it comes to evaluating quality, we ask the toughest judge in the world. YOU!



"Thank you for your recent order to Equipto Electronics Corporation," *Bob Golz, President*

At Equipto Electronics Corp., we want to be sure our quality control and service programs are meeting your needs…and you can help us.

By answering the following questions and mailing this postage-paid card back to us, you will help identify areas where we can become a better supplier to your company.

1. Your primary responsibility:
   ______Purchasing [✓ Engineering]
   Other (please state area of responsibility) ______
2. Equipto Electronics engineering support was:
   ______Not required [✓ Excellent] ______Good
   ______Poor ______Not available
3. Equipto Electronics customer service support was:
   ______Not required [✓ Excellent] ______Good
   ______Poor ______Not available
4. Quality of our products:
   [✓ Excellent] ______Good ______Poor
   Remarks: ______
5. Equipto Electronics delivery was:
   [✓ As promised] ______Late
6. Was there freight damage on this order?
   [✓ No] ______Yes If "yes" ______Carrier Damaged
   ______Improperly Packed
7. In what state is your plant or office where this order was received? MISSOURI

If you have suggestions on how we can better serve your company's needs or other comments, please provide them in the space below.

______

Optional Information:

Name DAVID C. MAINER SR
Title DESIGN ENGINEER
Company MC DONNELL DOUGLAS
Address PO BOX 516, D257/MC. 102111
City ST. LOUIS State MO Zip 63166
Telephone (314) 234-9010

Please fold this card over and tape it closed so our address shows on the outside, and mail—no postage is necessary. Thank you.

Q-88

Used with permission of David C. Mainer, Sr. and the McDonnell Douglas Corporation

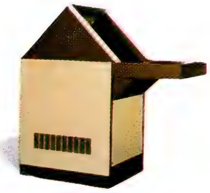
After each order of Equipto Electronics enclosures is delivered, we ask the customer to rate our quality and performance in five important areas. Here's how customers indicated we scored over a recent nine-month period:

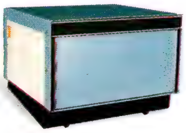
CATEGORY	SUMMARY
Product Quality	100.00% Excellent or Good
Engineering Support	99.938% Excellent or Good
Customer Service	99.875% Excellent or Good
On-Time Delivery	99.562% "As Promised"
Quality of Packing	99.938% Damage Free Packing

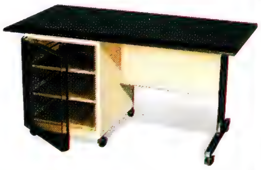
We know our reputation is on the line every time you specify and buy Equipto Electronics enclosures. You can't afford alibis and excuses. Neither can your company. Neither can we. That's why everyone at Equipto Electronics is specially trained to understand, respect and carry out the principles of quality manufacturing and service.

We invite you to see our Quality Control Program in operation. Call us to arrange an inspection of our facility. Or, request a copy of our "Quality Control and Inspection Manual" which also lists the military specifications we meet.

Our customer surveys indicate we're delivering products and performance you can count on time after time after time. We ask you to think about this the next time you order electronic enclosures.







Committed to Excellence Since 1960

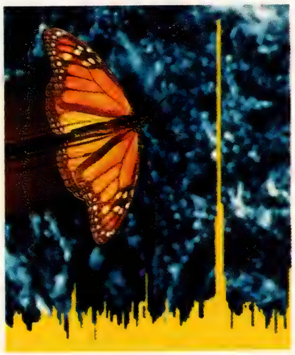
EQUIPTO
Electronics Corporation®

©Equipto Electronics Corporation, 1990

Equipto Electronics Corporation
351 Woodlawn Avenue • Aurora, Illinois 60506-9988
Phone (708) 897-4691 • FAX (708) 897-5314

Circle No. 25 On Reader Service Card

Our A/D's Were Designed to Give You Butterflies*!



True 14-Bit Performance at 1 & 2 MHz Sampling Rates

Analogic's new, ultra stable 14-bit sampling A/D converters make the most of your post-processing computations. Using advanced hybrid and surface mount technology, these sampling A/D's provide the most cost-effective solution to your high speed, high resolution applications.

This new family of sampling A/D's, designed for low noise and low distortion, provides 14 bits of resolution with true 14-bit performance. An 84 dB signal-to-noise ratio and our guarantee of no missing codes over an operating temperature range of 0ºC to 60ºC make these units unique. The ADC3110 in the frequency domain and the ADC3111 in the time domain will digitize signals up to 1 MHz at a 2 MHz rate, thus achieving unprecedented speed vs. accuracy performance. The ADC3214 has a 1 MHz sampling rate and is packaged as a compact 2" x 3" hybrid.

Our new sampling A/D's will perform superbly in your most demanding OEM applications. Digital oscilloscopes, waveform analysis, high speed data acquisition, sonar and digital signal processors. Whatever your DSP needs, Analogic has a sampling A/D to help you catch the butterflies...*fast*.

We even pledge it in writing. Unlike other manufacturers, Analogic puts all our sampling A/D's through exhaustive tests on our proprietary automatic test systems. The test data shipped with each product is our proof that it meets or exceeds our published specifications. What else would you expect from the world resource for A/D converter technology?

---

* The illustrated flow graph of the Cooley-Tukey algorithm is known in the industry as a butterfly computation.

For Application Assistance: Richard Lentini
Analogic Corporation, 360 Audubon Road,
Wakefield, MA 01880 (508) 977-3000 X2170
Telex: 466069, Fax: (617) 245-1274

CIRCLE NO. 117

ANALOGIC®
The World Resource for Precision Signal Technology

NEW PRODUCTS

TEST & MEASUREMENT INSTRUMENTS

Radio-Frequency Finder/Counter

- *Usable as handheld counter from 10 Hz to 2.4 GHz*
- *Accurate to ±1 ppm*

The model 2210A is a handheld unit that functions as a radio-frequency receiver and frequency counter. It covers 10 Hz to 2.4 GHz with a frequency accuracy of ±1 ppm. The unit has two ranges—10 Hz to 12 MHz with 1-MΩ input impedance and 10 MHz to 2.4 GHz with 50Ω impedance. The upper range incorporates a 256× prescaler. The 8-digit LED display provides 1-Hz resolution on the lower range and 100-Hz resolution on the higher range. The unit receives power from four rechargeable NiCd batteries or from an external source of 9 to 12V dc. Five optional plug-in antennas are optimized for operation in different frequency bands. $219.

Optoelectronics Inc, 5821 NE 14th Ave, Fort Lauderdale, FL 33334. Phone (800) 327-5912; in FL, (305) 771-2050. FAX (305) 771-2052.

Circle No. 351

Logic- And Memory-Device Programmer

- *Updates supported-device list via memory cards*
- *Programs EPROMs and EEPROMs to 40 pins*

The 212 Multi Programmer supports programmable CMOS logic devices to 24 pins and, via interchangeable modules, programs EPROMs and EEPROMs to 40 pins. Another module permits it to program most 1-chip microcontrollers. The programmer uses credit-card-sized memory cards to update its list of supported devices and programming algorithms. The standard complement of RAM is 256k bytes and is expandable to 1M byte. Configured to program memory and logic devices, $2000.

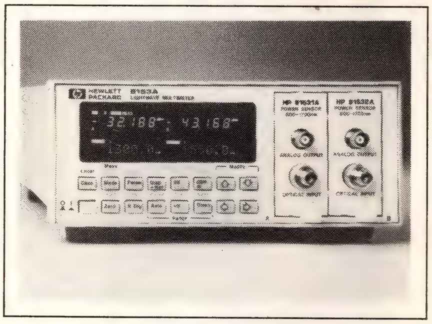
Data I/O Corp, Box 97046, Redmond, WA 98073. Phone (800) 247-5700; in WA, (206) 881-6444. FAX (206) 882-1043. TLX 152167.

Circle No. 352

Lightwave Multimeter

- *Uses plug-ins to measure power and return loss*
- *Accommodates two modules at once*

The HP 8153A lightwave multimeter helps you characterize and test fiber-optic components. You configure the benchtop unit by plugging in source and receiver modules—it accommodates two. A single unit can measure power, loss, and return loss. Laser source modules produce an output of 0 dBm at 850, 1310, and 1550 nm; they are stable to ±0.003 dB. A dual-wavelength module produces 1310 and 1550 nm. Power modules measure with an absolute accuracy of 2.5% and a linearity of ±0.015 dB. Sensitivities range from −70 to −110 dBm. The IEEE-488 command syntax fol-



Time To Market

Time to market... the span between inspiration and product introduction. You want the shortest path to a successful product launch — but all too often the system power supply becomes a stumbling block . . . development delays, safety agency approvals, EMI/RFI testing, size problems, cooling issues, cost overruns, last minute changes in power requirements, manufacturing disasters...no matter how innovative your product, you know that your customer's satisfaction — and your market opportunity — may ultimately hinge on how well your "custom" power system holds up.

FlatPAC takes the uncertainty out of power development by offering unprecedented flexibility along with instant availability...in a fraction of the space required by conventional switchers. You define your requirements...output power from 50 to 600 Watts; one to three outputs; output voltages from 2 to 95 Volts...we combine our high power-density converters with modular package and front-end assemblies to configure a FlatPAC specific to your needs. You benefit from the proven field performance and inherently high reliability of our component-level power converters, without sacrificing features: UL/CSA/TUV recognition, 110/220 VAC input, surge limiting, Class A EMI/RFI, OVP, overcurrent protection, all outputs totally isolated and trimmable, sequenced AC and DC status signals...and more.

Vicor believes that power should be the least of your problems. Let us show you how FlatPAC can help you win the race to market.

1-800-735-6200

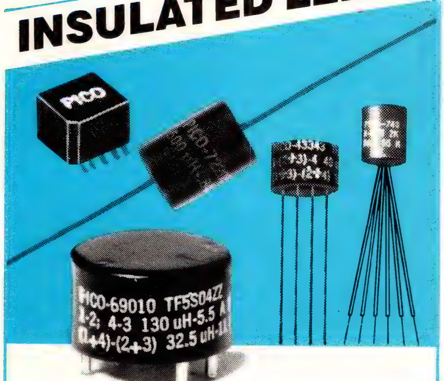
Component Solutions For Your Power System
23 Frontage Road, Andover, MA 01810

VICOR
Common Stock traded on NASDAQ under **"VICR"**

CIRCLE NO. 118

PICO POWER INDUCTORS

PLUG-IN
SURFACE MOUNT
AXIAL INDUCTORS
TOROIDAL
INSULATED LEADS



PICO's Ultra-Miniature Power Inductors are ideal for Noise, Spike and Power Filtering Applications in Power Supplies, DC-DC Converters and Switching Regulators.

- QPL standards available MIL-T-27/356
- Temperature range −55°C to +130°C
- All units are magnetically shielded
- All units meet the requirements of MIL-T-27 (TF5S04ZZ)
- Minimum possible size
- Split windings
- Inductance values to 20mH with DC currents to 23 amps

PICO manufactures complete lines of Transformers, Inductors, DC-DC Converters and AC-DC Power Supplies

Delivery—
stock to
one week

SEE EEM,
THOMAS REGISTER
OR SEND DIRECT FOR
FREE PICO CATALOG

PICO
Electronics, Inc.
453 N. MacQuesten Pkwy. Mt. Vernon, N.Y. 10552

Call Toll Free 800-431-1064
IN NEW YORK CALL 914-699-5514

CIRCLE NO. 22

lows test-and-measurement systems language. $4600 to $18,000. Delivery, six weeks ARO.

Hewlett-Packard Co, 19310 Pruneridge Ave, Cupertino, CA 95014. Phone (800) 752-0900. **Circle No. 353**

Digital Instrumentation Tape Recorder

- *Stores 426 hours of data on standard video cassette*
- *Records analog data to 80 kHz and has 70-dB dynamic range*

The RSR 512 rotary storage recorder digitizes analog data and uses helical-scan technology to record it on standard ½-in. video cassettes. A cassette that stores 120 minutes of TV programs at normal tape speed will record from 50 minutes to 426 hours of analog data from as many as 32 signal sources. At the fastest tape speed, the unit will store data with an 80-kHz bandwidth; dynamic range is 70 dB. The unit includes IEEE-488, RS-232C, and TTL remote interfaces. It can provide output data in both analog and digital form. A universal ac-operated power supply is standard; an ac/dc unit is optional for mobile applications. $20,000 for an 8-channel recorder; $50,000 for a 32-channel recorder.

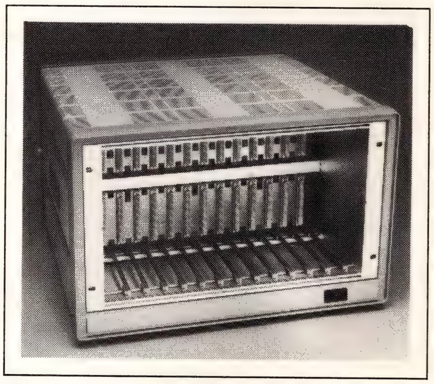
Honeywell Inc, 5105 E 41st Ave, Denver, CO 80216. Phone (303) 773-4835. **Circle No. 354**

Universal Device Programmer

- *Without adapters, programs PROMs, µCs, and PLDs*
- *Includes 115.2k-bps RS-232C port*

The AP III universal device programmer allows programming of the following device types without adapters: EPROMs and EEPROMs (to 4M bits with 8- and 16-bit data paths), bipolar PROMs, microcontrollers, and most families of PLDs. For downloading data, the unit includes a high-speed RS-232C port, which operates at 115.2k bps—six times the top speed of most such ports. The programmer, which has its own 16-bit µP, a battery-backed configuration memory, and as much as 4M bits of internal RAM, operates in a stand-alone mode. You can also operate it in the remote mode by connecting it to an IBM PC-compatible computer. The software that accompanies the programmer provides a menu-driven interface on the PC. DM 5498 plus value-added tax.

Owen Electronic GmbH, Ringstrasse 11, 6798 Kusel, West Germany. Phone (06381) 5085. FAX (06381) 8584. **Circle No. 355**



VXIbus Backplanes

- *Include models for A-, B-, C-, and D-size modules*
- *Include 5- and 13-slot units*

The vendor's VXIbus backplanes conform to Rev 1.3 of the VXI spec and accommodate A-, B-, C-, and D-size modules. There are 5- and 13-slot units. Nine-slot units should be available by the time you read this item. The backplanes have 10 circuit layers and include an active Sun bus protection module and an ECL buffer for the 10-MHz clock. Front-accessible DIP switches are mounted between connector slots to simplify configuring the bus-grant and interrupt-acknowledge daisy chains. A 5-pin header allows connection to the following signals: ACFAIL, SYSTEM_FAIL, SYSTEM_RESET, GROUND, and

CLOCK. 13-slot unit with J1 and J2 connectors, $1037; 5-slot unit with J1 and J2 connectors, $596.

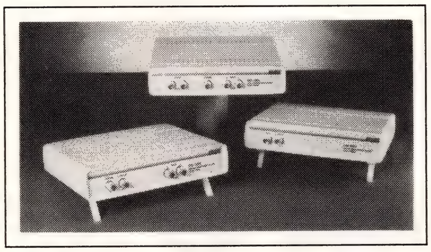
Interlogic Industries, 85 Marcus Dr, Melville, NY 11747. Phone (516) 420-8111. FAX (516) 420-8007. **Circle No. 356**

PC-Based Data-Acquisition System

- *Has 16 channels and a 12-bit ADC*
- *Simultaneously records and processes 1-MHz signals*

The EGAA system includes an IBM PC bus plug-in card, a BNC coaxial-connector panel, and software. The board contains a 12-bit ADC that can make 1M conversions/sec, 64k words of RAM, and a 16-channel multiplexer. The software allows the hardware to function as a digital storage scope, and, optionally, as a chart recorder. On an 80386-based PC, it permits logging of data to disk at maximum speed while also performing some processing functions. Among the software options are averaging, histogram displays, and calculation of FFTs. The system runs a variety of hardcopy graphics output devices. $2495. Software analysis options, $795 to $1495.

RC Electronics Inc, 5386-D Hollister Ave, Santa Barbara, CA 93111. Phone (805) 964-6708. FAX (805) 964-4906. **Circle No. 357**

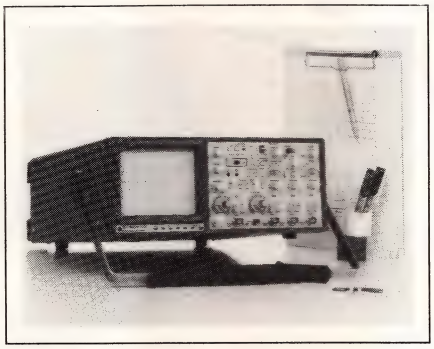


Analog I/O Subsystems

- *External units connect to DSP processor inside PC*
- *Permit choice of resolution and speed*

The ZPD Series of analog I/O subsystems are intended for use with the vendor's IBM PC-compatible DSP boards. The series includes three units that mount outside the PC and communicate with the DSP boards via an on-card serial port operating under DMA control. The ZPD1001 is a 16-bit I/O card that takes 150k samples/sec and achieves a dynamic range of 93 dB. The ZPD1002 includes a 12-bit ADC that takes 10M samples/sec. Both 1- and 2-channel versions are available. The ZPD1003 is a 16-bit analog-input unit that takes 500k samples/sec. ZPD1001, from $1249; ZPD 1002, from $2495; ZPD1003, from $2295.

Burr-Brown Corp, Box 11400, Tucson, AZ 85734. Phone (800) 548-6132; in AZ, (602) 746-1111. FAX (602) 889-1510. **Circle No. 358**

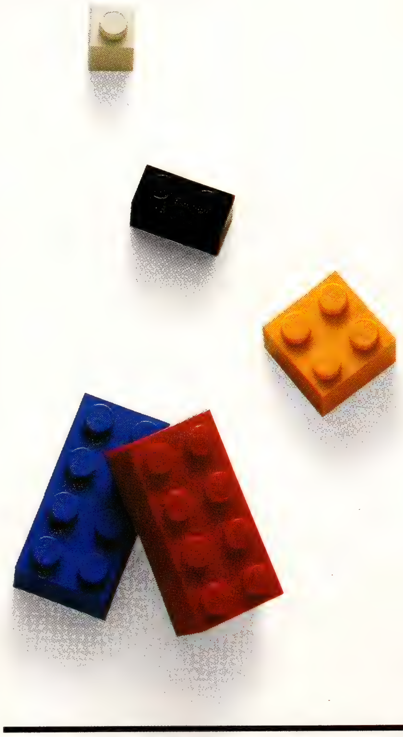


100M-Sample/Sec, 4-Channel DSO

- *Has 100-MHz bandwidth on all channels in repetitive mode*
- *Includes RS-232C and plotter interfaces*

The VC-6145 digital oscilloscope has four channels. It has a total sample memory of 4k words and takes a total of 100M samples/sec, regardless of how many channels are active. In repetitive (equivalent-time-sampling) mode, analog bandwidth is 100 MHz on all channels. A sweep-time autoranging feature automatically sets the time range. Other features include signal averaging, a choice of linear or sine-wave interpolation, an X-Y display, cursor measurements, a built-in

You're About To See A New Interconnect System That's As Modular As This.



Du Pont Electronics
Share the power of our resources.

DU PONT

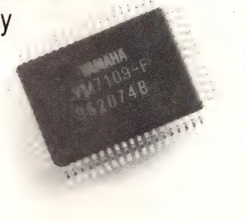
"Voice Capability in a FAX Modem Chip from Yamaha LSI!"

"Now We're Talking!"

Smart PCs and FAX machines are spreading the word. Because now they can have complete voice recording and playback capability! Easily. And quickly. With Yamaha's YM7109 FAX Modem chip and FAXSIM™ software.

The YM7109 gives designers a voice/FAX solution in a single chip. It provides a complete send/receive 9600bps Group 3 FAX Modem. Plus, 12-bit A/D and D/A converters sampling at 9.6k samples/second for high resolution voice processing. And voice quality that surpasses even today's digital telephone systems.

The YM7109 opens up a new world of applications. A FAX machine can answer phone calls and record messages. A PC can provide added utility as a FAX and telephone answering machine. Or a FAX board can greet callers and send requested information. The possibilities are endless.



But remember, those who get to market first — are the winners. That's where Yamaha's FAXSIM software gives you a head start. It includes all the FAX modules, plus Bulletin Board Service using EIA Binary File Transfer/Bell 103, and ADPCM for storing and playing back voice. The source code is available in Turbo C™ and makes integration a breeze. Letting you move from design to production fast.

Beat the competition. Call us at 1-800-543-7457. We'll get your PCs and FAX machines talking.

YAMAHA® LSI

Systems Technology Division
981 Ridder Park Drive, San Jose, CA 95131

© 1990, Yamaha LSI, Systems Technology Division. Yamaha LSI, Systems Technology Division and the Yamaha logo are registered trademarks of Yamaha Corporation of America. FAXSIM is a trademark of Yamaha Corporation of America. Turbo C is a trademark of Borland Corporation.

EDN INFO CARDS

THE 2¢ SOLUTION

to your marketing budget blues – the EDN Info Card Pack. At 2¢ per name, the EDN Info Card Pack can reach over 123,000 engineering specifiers affordably.

Contact Donna Pono EDN Info Cards, (617) 558-4282

EDN Magazine Edition News Edition

A Partnership in Power and Prestige Worldwide

100-MHz frequency counter, and RS-232C and plotter interfaces. $5295.

Hitachi Denshi America Ltd, 150 Crossways Park Dr, Woodbury, NY 11797. Phone (800) 645-7510; in NY, (516) 921-7200. FAX (516) 496-3718. **Circle No. 359**

Data-Acquisition Software

- *Works with IBM PC bus data-acquisition boards*
- *Works with AutoCAD and Lotus 1-2-3*

Aimax-Plus/Lab software controls IBM PC bus data-acquisition boards from Strawberry Tree Inc, Data Translation Inc, and Advantech. Among the package's features is on-line Lotus 1-2-3, which permits the input and output of data directly from the popular spreadsheet. The software is also compatible with AutoCAD: Using the .DXF file format, the software can load AutoCAD files and maintain their object orientation. You can view the files in what-you-see-is-what-you-get format; you can also zoom in and out and edit the files. According to the vendor, the software handles the alarm requirements of large digital control systems. Licensed copies, $995; demonstration disk, $50.

TA Engineering Co Inc, Box 186, Moraga, CA 94556. Phone (415) 376-8500. FAX (415) 376-4977. **Circle No. 360**

Filter Substitution Boxes

- *Permit push-button selection of four filter types*
- *Let you choose cutoff frequencies from 0.001 Hz to 200 kHz*

The Model 3000 series Flexi-Filters include four channels. For each channel, you can use a pushbutton to select Butterworth, Bessel, Chebyshev, or RC response with an attenuation slope of 6 to 48 dB/octave. You can tune the cutoff frequency from 0.001 Hz to 200 kHz.

You're About To See A New Interconnect System That Brings High-Density Packaging Down To This.

Du Pont Electronics
Share the power of our resources.

DU PONT

Because you're thinking fast...

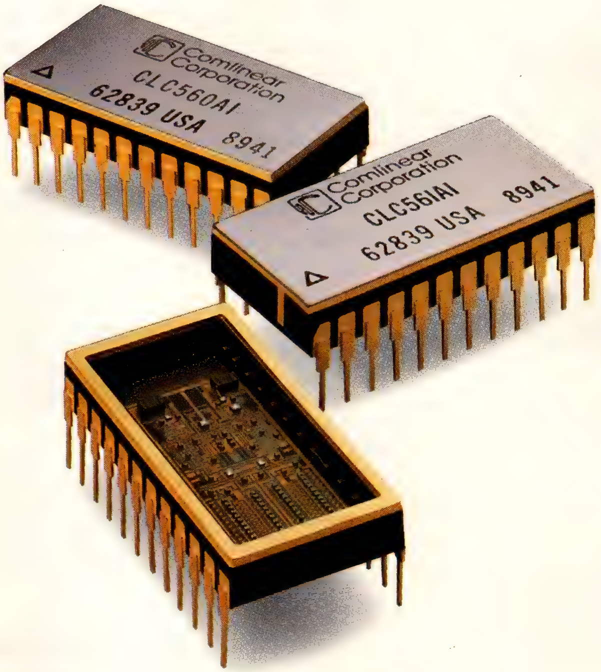
you need responsive suppliers as well as fast parts. Comlinear is tuned in. With high quality, high-speed products. Assistance from R&D-level applications engineers to help develop your ideas quicker. Off-the-shelf MIL-STD-883 compliant monolithics and hybrids. Quality product documentation with guaranteed specs so you don't waste time. In your business, time is everything. Count on us for the speed you need.

Introducing the DriveR-*amps*™... power them up and drive away.

Now, you have alternatives to in-house driver-amplifier designs. Because Comlinear is announcing the first two in a class of off-the-shelf DriveR-*amps*.

You've never seen amplifiers like these before. With high drive they handle difficult loads at high speed. 2nd and 3rd harmonic distortion are a low -51 and -48dBc (18dBm, 20MHz). Plus, user-defined output resistance eliminates backmatching resistors.

Pick the CLC560, with 10ns settling to 0.1%, for driving in the time-domain... pulse and arbitrary waveform generators, for example. Or the CLC561, with minimum 135MHz large-signal ($10V_{pp}$) bandwidth, for frequency-domain designs such as sine-wave generators/synthesizers. Both are great A/D drivers. So wherever you're heading, find out how to improve your driving... fast.



Comlinear Corporation
Solutions with speed

4800 Wheaton Drive
Fort Collins, Colorado 80525
(303) 226-0500
Fax (303) 226-0564

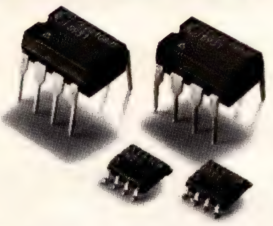
©1990 Comlinear Corporation

For more information, contact the representative in your area.

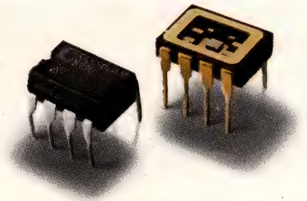
Country	Representative	Phone
Belgium	Tekelec Airtronic	02-360.12.88
Ireland	Joseph Electronics, Ltd.	44-21-643-6999
Italy	MicroElit S.P.A.	02-4817900
Spain	Anatronic, S.A.	91-5424455
United Kingdom	Joseph Electronics, Ltd.	021-643-6999
France	Micro Puissance	1-69.07.12.11
Israel	Elul Technologies	3-264161
Netherlands	Tekelec Airtronic	079-310100
Switzerland	Transtech Hochfrequenz AG	56-27 18 93
West Germany	Transtech Hochfrequenz GMBH	089-843017

CIRCLE NO. 124

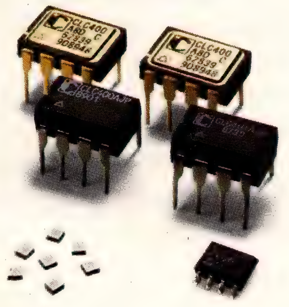
And get a view of these fast op amps...



High-speed video op amp with disable.
The new 200MHz CLC410, with a 200ns disable function, has differential gain/phase specs of 0.01%/0.01°. Power consumption is 160mW on, 40mW disabled. Ideal for video switching/distribution and low-power applications.
CIRCLE NO. 125



Fast 12-bit clamping amp.
For A/D and D/A converter designs, the CLC502 settles to 0.01% in 18ns. It has output clamping to protect sensitive loads. Plus fast overload recovery so overdrive signals don't mask important information.
CIRCLE NO. 126



150/200MHz, 10ns settling, low cost.
Our 200MHz low-gain and our 150MHZ high-gain op amps offer high performance at low cost. Both the CLC400 and 401 have 10ns settling to 0.1%. Versions are available in MIL-STD-883, PDIP, SO-8, industrial ceramic and die.
CIRCLE NO. 127

You can also adjust the input and output gains to 10,000 in 0.1-dB steps. Options include one or two oscillators, battery power, and control of all parameters via the IEEE-488 bus. $1995 to $3600.

Krohn-Hite Corp, Avon Industrial Park, Bodwell St, Avon, MA 02322. Phone (508) 580-1660. FAX (508) 583-8989. **Circle No. 361**

DSP Development Systems

- *Can be used to characterize ADCs and develop software*
- *Accommodate two 64k-word buffers*

The DSP-SYS603 and DSP-SYS701 are IBM PC-based development systems that include, respectively, the vendor's 12-bit, 10M-sample/sec ADC603 and its 16-bit, 500k-sample/sec ADC701. Both systems include a board that you plug into the PC's bus. The board houses a 50-MHz Western Electric DSP32C processor chip and 576k bytes of RAM. The ADCs are housed in small enclosures that you mount outside the PC. Besides an ADC, the enclosures can hold one or two 64k-word buffers. Accompanying the hardware is mouse-driven software that converts the PC into a DSO, a spectrum analyzer, or a histogram analyzer. From $8995.

Burr-Brown Corp, Box 11400, Tucson, AZ 85734. Phone (602) 746-1111. FAX (602) 889-1510.
Circle No. 362

Programmable, 125-MHz Pulse Generator

- *Has separate positive and negative outputs*
- *Features individually programmable rise and fall times*

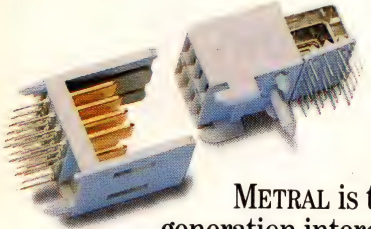
Outputs from the PM 5781 pulse generator cover 0.1 to 125 MHz. An extended low-frequency range lets the instrument produce pulses at a rate of 25 μHz—just over two pulses every 24 hours. You can pro-

Text continued on pg 220

You're About To See A New Interconnect System That's As Multi-Functional As This.

DuPont Electronics
Share the power of our resources.
DUPONT

Introducing The Universal



METRAL is the next generation interconnect system that's meeting today's need for greater density, modularity, flexibility, and functionality.

And that's just the beginning.

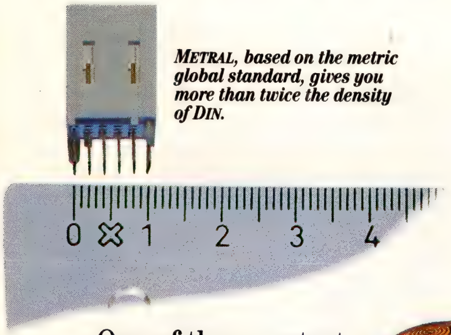
METRAL cuts costs by shortening the design cycle.

It reduces risk by being flexible enough to allow for design changes.

And METRAL is universal enough to use in electronic packaging designs from modems to mainframes.

With all these advantages, it's no wonder METRAL was selected by IEEE as the interconnection standard for Futurebus+.

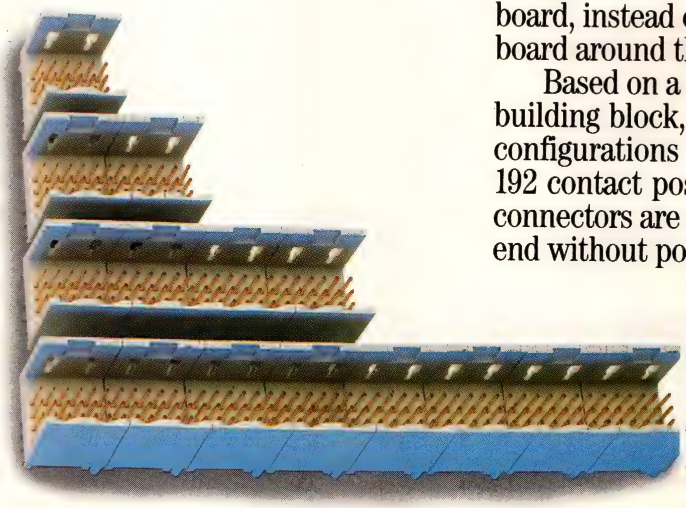
Over 2 Times The Density of DIN.



METRAL, based on the metric global standard, gives you more than twice the density of DIN.

One of the smartest features of METRAL is that it's designed with today's—and tomorrow's—high density requirements in mind.

METRAL connectors are based on a 2.0 millimeter grid (an excellent balance of density, cost and durability), and provide up to 456 signal positions on a double Eurocard. Which means, in the same amount of space, METRAL packs more than twice the position density of DIN 41612.



METRAL offers stackable end-to-end configurations of 24, 48, 96 and 192 contacts—without position loss.

Affordable, cost-effective density like that makes METRAL indispensable if you want the most value possible from available real estate.

To put it another way, the more functions you pack on a board, the more you need METRAL.

With This Much Modularity, You Can't Lose.

Because of its uniform module design, METRAL is remarkably adaptable. This allows you to design the connectors around the board, instead of designing the board around the connectors.

Based on a 4x6 position building block, METRAL offers configurations of 24, 48, 96 and 192 contact positions. And the connectors are stackable end-to-end without position loss. You can use the same footprint for signal and power modules. If you don't need a module, the space saved on the board can be used for something else.

METRAL also has keying and coding features for mistake-proof assembly.

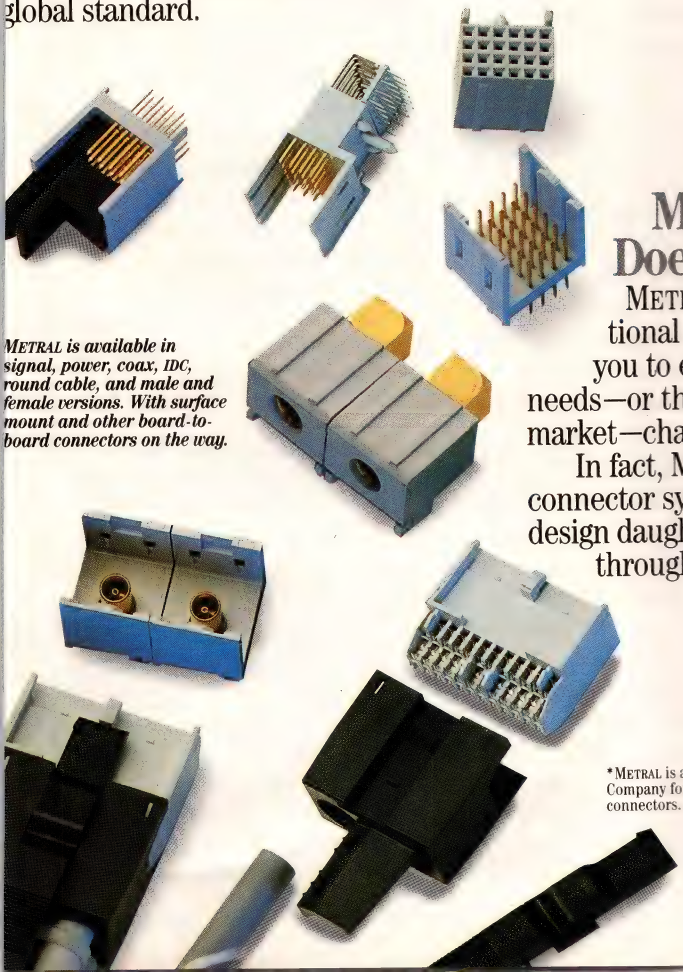
Du Pont METRAL.* Interconnection System.

The Universal Standard.

Thanks to its "building block" approach, METRAL affords designers limitless creativity by standardizing the configuration of the connectors. That means you can standardize across your entire product line—whether data processing, telecommunications or instrumentation.

What's more, since METRAL connectors can be qualified as a system, you can reduce approval time.

And with metric standardization on the way, designing with METRAL makes even more sense. Because METRAL already meets the metric global standard.



METRAL is available in signal, power, coax, IDC, round cable, and male and female versions. With surface mount and other board-to-board connectors on the way.

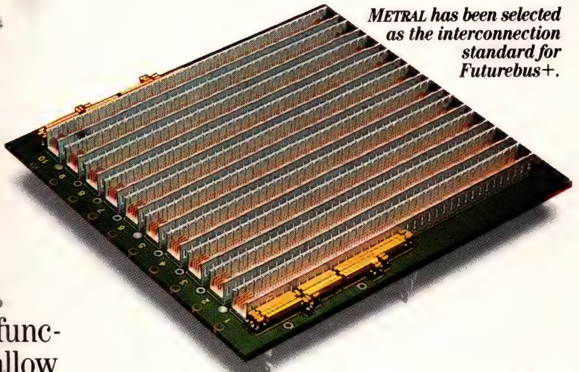
METRAL Does It All.

METRAL is multifunctional enough to allow you to expand as your needs—or the needs of the market—change.

In fact, METRAL is the first connector system that lets you design daughter cards for through-hole or surface mount without redesigning the backpanel system.

METRAL is available in signal, power, coax, IDC, round cable and male and female solder-to-board versions. And shielded cable connectors, surface mount, fiber optic, press-fit and high speed board-to-board connectors are on the way.

Make The Move To METRAL.



METRAL has been selected as the interconnection standard for Futurebus+.

The first step is to call **1-800-237-4357.** We'll send you more information about the one connector system that can meet your needs today—and tomorrow—for more density, modularity and flexibility. METRAL.

DuPont Electronics

Share the power of our resources.

DUPONT

---

*METRAL is a trademark of the DuPont Company for its family of electronic connectors.

ic®
ELECTROLYTIC CAPACITORS

SUB-SUBMINIATURE LO-PROFILE ELECTROLYTICS
RSS
0.1 Mfd. To 3,300 Mfd.
6.3 WVDC To 50 WVDC
−40°C To +85°C Min.
Solvent Tolerant &
Epoxy Seal Opt.
Tape & Reel Available

COMMERCIAL/INDUSTRIAL ELECTROLYTICS
TTA
0.47 Mfd. To 33,000 Mfd.
6.3 WVDC To 500 WVDC
−40°C To +85°C Min.
2000 Hr. +85°C
Solvent Tolerant &
Epoxy Seal Opt.
Tape & Reel Available

HIGH FREQUENCY +105°C ELECTROLYTICS
RZS
22 Mfd. To 2,200 Mfd.
6.3 WVDC To 63 WVDC
−55°C To +105°C Min.
Hi-Ripple @ 100 KHz
Low ESR, Low ESL
Solvent Tolerant Std.
Tape & Reel Available

LOW-LEAKAGE ALUMINUM ELECTROLYTICS
RLR (Radial)
0.1 Mfd. To 2,200 Mfd.
TLA (Axial)
0.1 Mfd. To 100 Mfd.
6.3 WVDC To 50 WVDC
−40°C To +85°C Min.
Leakage Current:
≤0.002 CV or 0.4 μA min.
Solvent Tolerant &
Epoxy Seal Opt.
Tape & Reel Available

SUBMINIATURE ELECTROLYTICS
CKR (+85°C) • RMR (+105°C)
0.1 Mfd. To 15,000 Mfd.
6.3 WVDC To 250 WVDC (CKR)
6.3 WVDC To 450 WVDC (RMR)
-40°C To +85°C (CKR)
-40°C To +105°C (RMR)
Solvent Tolerant Std. (≤250 WVDC)
Epoxy Seal Opt.
Tape & Reel Available
• 125°C ELECTROLYTICS
• NON-POLAR ELECTROLYTICS
• SNAP-MOUNT ELECTROLYTICS

ic®
ILLINOIS CAPACITOR, INC.
3757 West Touhy Avenue
Lincolnwood, Illinois 60645
(708) 675-1760
Fax (708) 673-2850

CIRCLE NO. 128

gram the output pulses' rise and fall times from 2 nsec to 100 msec. There are separate outputs for positive and negative pulses as well as a third output that you can switch to provide TTL or ECL levels. You can control the dc offset added to the negative pulses. Internal 50Ω matching resistors minimize distortion. The generator produces continuous pulses, or, in response to a trigger, single pulses, double pulses, and pulse bursts. It also produces gated pulse bursts and square waves. A back-lit LCD displays 10 pulse parameters. $9585. Delivery, 12 weeks ARO.

John Fluke Mfg Co Inc, Box C9090, Everett, WA 98206. Phone (800) 443-5853, ext 77.

Circle No. 363

Philips Test and Measurement, Bldg HKF, 5600 MD, Eindhoven, The Netherlands. Phone local office.

Circle No. 364

4- And 8-Channel DSOs

- *Include internal 4-color plotters*
- *One measures signals 500V from ground*

The 2608 is an 8-channel DSO; the 1624 is a 4-channel unit. Both scopes take a maximum of 20M samples/sec, store 10k samples/channel, and permit the installation of waveform processors that perform calculations on acquired data. The scopes can also accommodate 4-color plotters. The 8-channel unit has signal inputs that are ohmically isolated from the chassis and can operate in the presence of ±500V common-mode voltages. The differential inputs of the 4-channel unit, which can withstand ±300V common-mode voltages over much of their input range, guarantee a common-mode rejection ratio of 70 dB at dc and 54 dB at 1 kHz. 4-channel unit, from $8790; 8-channel unit, from $13,300. Delivery, 45 days ARO.

Gould Inc, 3631 Perkins Ave, Cleveland, OH 44114. Phone (216) 361-3315.

Circle No. 365

Lowest Profile
0.5″ ht.,
up to 55 Watts

PICO
AC-DC
Power
Supplies

- Input Voltage 90 to 130 VAC (47/440Hz)
- Single, Dual, Triple Outputs
- 1200V Rms Isolation
- Low Isolation Capacity Available
- Continuous Short Circuit Protection
- High Efficiency
- Fully Regulated Voltage Outputs
- Operating Temperature −25°C. to +70°C. with No Heat Sink or Electrical Derating Required
- Expanded Operating Temperature Available (−55°C. to +85°C. ambient)
- Optional Environmental Screening Available

PICO manufactures complete lines of Transformers, Inductors, DC-DC Converters and AC-DC Power Supplies

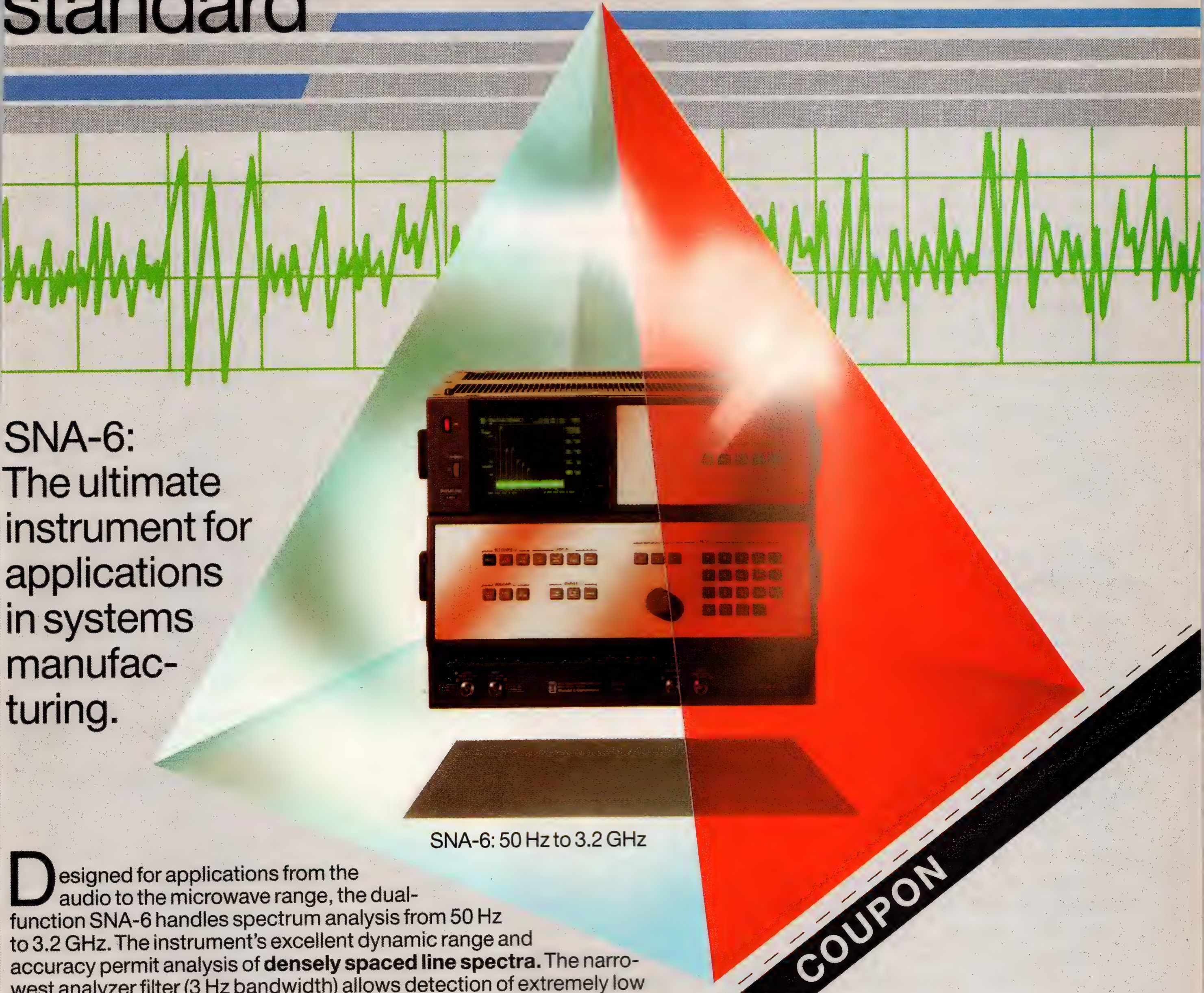
Delivery— stock to one week

SEE EEM, THOMAS REGISTER OR SEND DIRECT FOR FREE PICO CATALOG

PICO
Electronics, Inc.
453 N. MacQuesten Pkwy. Mt. Vernon, N.Y. 10552
Call Toll Free 800-431-1064
IN NEW YORK CALL 914-699-5514

CIRCLE NO. 23

The new performance standard



SNA-6: The ultimate instrument for applications in systems manufacturing.

SNA-6: 50 Hz to 3.2 GHz

Designed for applications from the audio to the microwave range, the dual-function SNA-6 handles spectrum analysis from 50 Hz to 3.2 GHz. The instrument's excellent dynamic range and accuracy permit analysis of **densely spaced line spectra.** The narrowest analyzer filter (3 Hz bandwidth) allows detection of extremely low amplitude a. c. line interference superimposed **on a 3 GHz carrier.** This is just one benefit of the low-noise synthesizer oscillator. The SNA-6 also sets new standards in scalar network analysis. The 0.1 Hz resolution synthesizer can be tuned across the entire frequency range without skips or phase hits. The same synthesizer also provides the signal for the tracking generator. When testing active two-port networks, the gain/attenuation vs. frequency can be determined from + 30 to − 140 dBm and 100 kHz to 3.2 GHz with excellent precision.

You can use our bar code reader or your PC with our software for remote control applications on the IEEE 488/IEC 625 bus. You will also be impressed by the versatile evaluation functions and hardcopy capabilities of the SNA-6.

For more information about the state-of-the-art SNA-6 from Wandel & Goltermann, please fill out and send in the coupon below.

USA: Wandel & Goltermann, Inc., 1030 Swabia Court, R. T. P., NC 27709, Tel. (919) 941-5730, Telex II: 810-621-0002, Fax (919)941-5751. **Canada:** Wandel & Goltermann Inc., 21 Rolark Drive, Scarborough, Ontario M1R3B1, Tel. (416) 291-7121. **Worldwide:** Wandel & Goltermann, VMW, Postfach 12 62, D-7412 Eningen, Tel. + (49) 7121-86-0, Tlx. 729833, Fax + (49) 7121-8 84 04.

CIRCLE NO. 129

COUPON

☐ More information about the SNA-6
☐ Please arrange for a sales engineer to call

Name ....

Company ....

....

Street ....

Town/postcode ....

Telephone no. ....

Wandel & Goltermann
Electronic Measurement Technology

E 10.89/VMW/14/4C/NA EDN051090
EM/10

LITERATURE

Note On Linear Circuits

AN31: Linear Circuits for Digital Systems explains how to design linear circuits for digital systems such as flash-memory programming. The publication discusses high-repetition-rate programming pulse supplies, programming pulse-voltage handshaking, and 5V-powered 4- to 20-mA current-loop generation. It also covers an ac line-dropout detector, a memory-save circuit, an overvoltage-protection circuit, a power-on-reset generator, watchdog timers, and a high-noise-immunity, line-synchronous clock.

Linear Technology Corp, 1630 McCarthy Blvd, Milpitas, CA 95035. **Circle No. 366**

Listing Of Boxer Axial Flow Fans

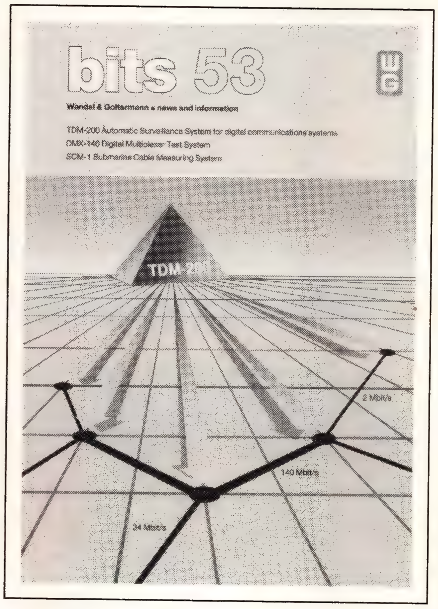
This 56-pg catalog provides application notes and general specifications of the company's boxer axial flow fans. It lists rated and operating voltage, input power, rated current, maximum air flow and air pressure, rotor speed, and noise level for each model. The listing of more than 100 dc and ac fans includes dc series' frame sizes from 60 to 120 mm^2, ac series' frame sizes from 60 to 172 mm^2, and airflow from 10 to 220 cfm. Also included are functional diagrams, engineering data, and performance curves. The catalog also deals with installation guides and accessories for each series as well as static-pressure, temperature-conversion, and airflow-conversion charts. It also includes an explanation of the parts-numbering system.

NMB Technologies Inc, 9730 Independence Ave, Chatsworth, CA 91311. **Circle No. 367**

T&M Products For PC-Based Instrumentation

The 20-pg catalog, *Your Complete Guide to PC-Based Instrumentation Systems,* describes more than 125 instruments, such as digital multimeters, digital storage oscilloscopes, signal sources, counters and timer/counters, data-acquisition instruments, and modular switching and I/O systems. The publication also highlights a line of test and measurement and data-acquisition software packages for PC-based systems, as well as the details of the company's service and support programs.

John Fluke Mfg Co Inc, Box C9090, Everett, WA 98206. **Circle No. 368**



bits 53

Wandel & Goltermann • news and information

TDM-200 Automatic Surveillance System for digital communications systems

DMX-140 Digital Multiplexer Test System

SCM-1 Submarine Cable Measuring System

Brochure Features Surveillance System

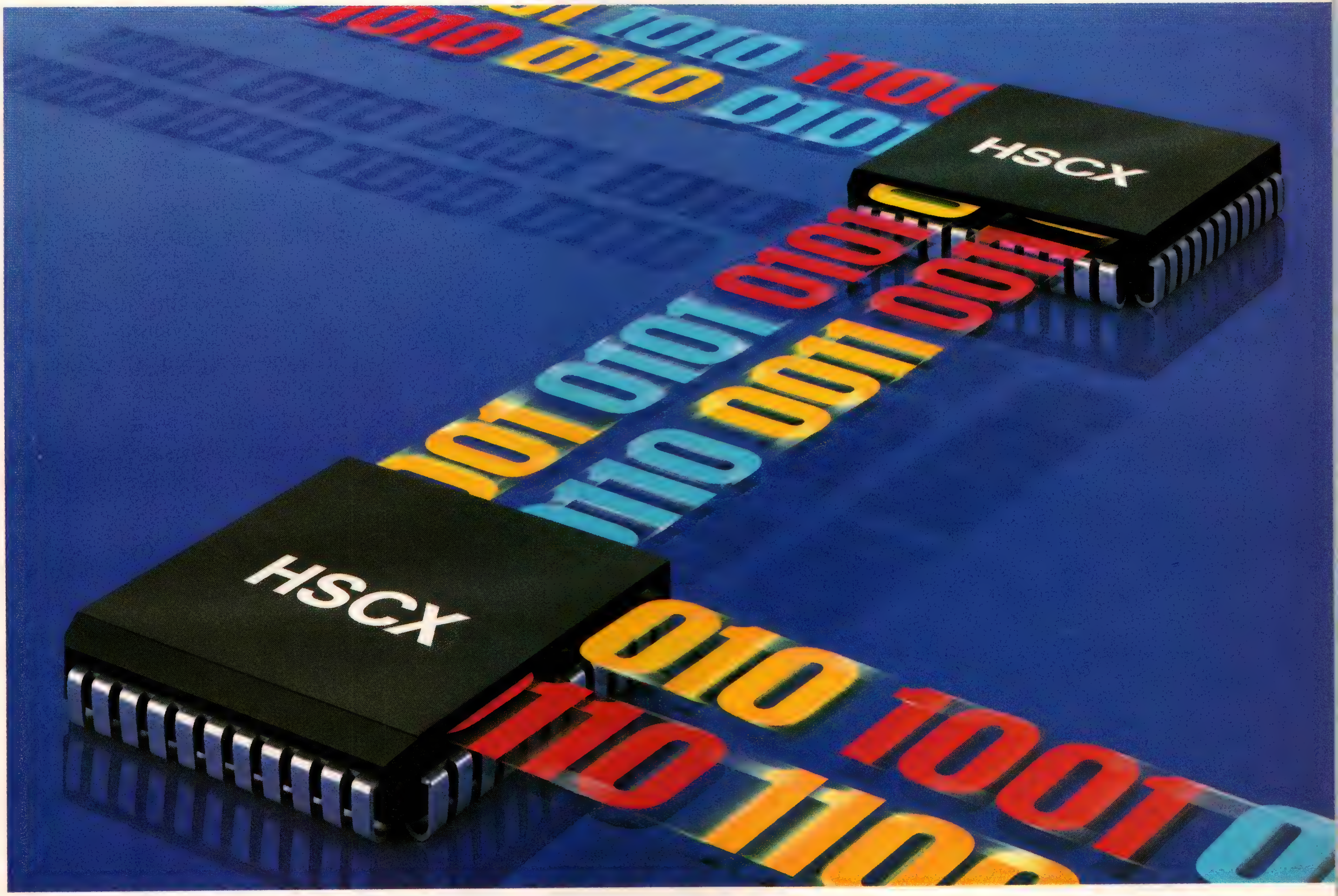
The December edition of *bits 53* covers a modern surveillance system for digital communications systems using bit rates as high as 140M bps. A report on recent developments of the DMX-140 digital-multiplexer test system, part 2 of the technical article "Signature measurements on digital RF communications systems," and two application notes round out the publication. This edition concludes with the 1989 index for *bits* editions 49 to 53.

Wandel & Goltermann, Electronic Measurement Technology, Postfach 12 62, D-7412 Eningen uA, West Germany. **Circle No. 369**

The best address for Siemens Semiconductors:

Ⓐ **Wien**
Tel. (0222) 71711-5661
(AUS) **Melbourne, Vic. 3121**
Tel. (03) 4207111
Ⓑ **Bruxelles**
Tel. (02) 536-2111
(BR) **São Paulo-SP**
Tel. (011) 833-2211
(CDN) **Mississauga L5T 1P2**
Tel. (416) 564-1995
(CH) **Zürich**
Tel. (01) 495-3111
Ⓓ **Berlin 10**
Tel. (030) 3939-1
Düsseldorf 1
Tel. (0211) 399-0
Frankfurt 1
Tel. (069) 797-0
Hamburg 1
Tel. (040) 2889-0
Hannover 81
Tel. (0511) 877-0
München 80
Tel. (089) 9221-4380
Nürnberg 1
Tel. (0911) 654-0
Stuttgart 1
Tel. (0711) 2076-0
(DK) **Ballerup**
Tel. (42) 656565
Ⓔ **Madrid**
Tel. (01) 5554062
Ⓕ **Paris**
Tel. (1) 4922-3810
(GB) **Sunbury on Thames**
Tel. (0932) 752615
(GR) **Amaroussio**
Tel. (01) 6864-111
(HK) **Hongkong**
Tel. 5-8330222
Ⓘ **Milano**
Tel. (02) 6766-4241
(IND) **Bombay 400018**
Tel. 4938786
(IRL) **Dublin**
Tel. (01) 302855
Ⓙ **Tokyo 100**
Tel. (03) 201-2401
Ⓝ **Oslo 5**
Tel. (02) 633000
(NL) **Den Haag**
Tel. (070) 3333333
Ⓟ **Alfragide**
Tel. (01) 4183311
(RA) **Buenos Aires**
Tel. (01) 300411
(RC) **Taipei**
Tel. (02) 5234700
(ROC) **Seoul**
Tel. (02) 275-6111
Ⓢ **Stockholm**
Tel. (08) 7281000
(SF) **Helsinki**
Tel. (9) 051051
(SGP) **Singapore 0513**
Tel. 7760044
(TR) **Istanbul**
Tel. (01) 1510900
(USA) **Iselin**
Tel. (201) 906-4300
Santa Clara
Tel. (408) 980-4500
Cupertino
Tel. (408) 725-7910
(ZA) **Johannesburg**
Tel. (011) 407-4111

SIEMENS



High Speed Communication.

Siemens has opened a whole new line of communication which now makes it easier to successfully combine high-speed data transfer with high-level data-link control.

The Siemens High-Level Serial Communication Controller (HSCX) has all the features you need for a successful communications system. The HSCX comes with two independent bi-directional channels, and has a storage capacity of up to 17 frames in its four on-chip 64 Byte FIFOs. At a transfer speed of up to 6 Mbit/s, it supports a number of synchronous standardized protocols (HDLC, LAPB/LAPD, X.25, SDLC), and a greater number of non-proprietary protocols.

And by inverting data into programmable time slots automatically, the HSCX considerably lowers your CPU overhead, as well as reducing external glue logic.

These features provide the potential for HSCX applications in a variety of fields, such as proprietary LAN controlling networks, assembly line LANs, fast diagnostic systems, and traffic systems), as well as standardized areas such as Switching Systems and ISDN (X.25, Terminal Adaptors, and Modems). For easy access to the wide variety and complexity of synchronous data transfer, Siemens also provides a PC-based evaluation kit.

The HSCX has already made a name for itself by providing the power needed to drive even the most complex communications systems. In fact, the biggest names in the industry already rely on the HSCX – with a great deal of success. Finally the HSCX will be sourced also by AMD. It's amazing what you can accomplish with good communication skills.

If that goes down well and you want to find out more, contact your local Siemens office or just write to:

Europe:
Siemens AG, Infoservice HL 1575,
Postfach 23 48, D-8510 Fürth

USA:
Siemens Semiconductor Group,
2191 Laurelwood Road,
Santa Clara, CA 95054
Quoting: „HSCX."

TopTech
Semiconductors
Siemens

MC&D

A19100-HL1575e90

CIRCLE NO. 130

The only chip we can't program

With Digelec programmers you can program devices of all major semiconductor manufacturers.

Consider four additional reasons to choose Digelec:

Choose Digelec for friendliness - Digelec programmers are easy to operate and lightweight.

Choose Digelec for cost-effectiveness - Compare features and price. You won't find any better.

Choose Digelec for up-to-date design capabilities - Regular software updates support latest device technologies.

Choose Digelec for your application - We've got the model you need. Universal or dedicated Memory/Logic programmer for R & D, Gang/Set or In-Circuit for production, and PC-based for budgetary applications.

Got a chip you need to program? Call (818)701-9677 in California or toll free 1-800-367-8750. We'll respond immediately.

digelec

USA: 20144 Plummer St., Chatsworth, CA 91311
Fax: 818-701-5040

W. Germany: Digelec GmbH
Brudermühlstrasse 42, 8000 Munich 70
Tel: 089-776-098 Fax: 089-725-9164

Supports almost every chip

CIRCLE NO. 28

Voluminous Listing Of Aluminum Capacitors

This 294-pg catalog presents a complete line of miniature, large-can, snap-mount, and tubular aluminum capacitors for commercial, industrial, and military applications. The publication highlights several capacitors: Type 510DX, a miniature radial-lead capacitor rated for 2000 hours at 125°C; Type 515D series miniature capacitors; Type 81D and Type 82D snap-mount capacitors; and Type 36DY large-can capacitors.

Sprague Technical Literature Services, Box 9102, Mansfield, MA 02048. **Circle No. 370**

How To Use Synchronous State-Machine PLD

Application note CY7C330 explains how to use Cupl, a PLD compiler, to program the Cypress CY7C330 synchronous state-machine PLD. The 8-pg publication helps you define the 258 product terms to design high-performance logic quickly and easily. The document describes macrocell configuration and hidden-register utilization.

Logical Devices Inc, 1201 NW 65th Pl, Fort Lauderdale, FL 33309. **Circle No. 371**

Volume Discusses Systems Programming

Systems Programming in Parallel Logic Languages, the third in a series discussing the technology of the Strand programming language, examines the application of parallel logic programming—a new approach to concurrent programming. Based on realistic applications, the book presents techniques to implement concurrent systems, particularly operating systems that use

30 YEARS OF RELIABILITY

A POWERFUL STATEMENT

Full Line of DC/DC Converters and AC/DC Power Supplies

- Narrow and Wide Range Inputs from 4 to 400 VDC
- AC Inputs from 90 to 270 VAC
- Switching and Linear Designs
- Encapsulated
- Outputs from 2 to 3000 VDC
- Outputs: Single, Dual or Triple; Isolated or Non-Isolated; Regulated or Unregulated
- Low Profile, PC Board Mountable

Since 1960: a Power in the Industry

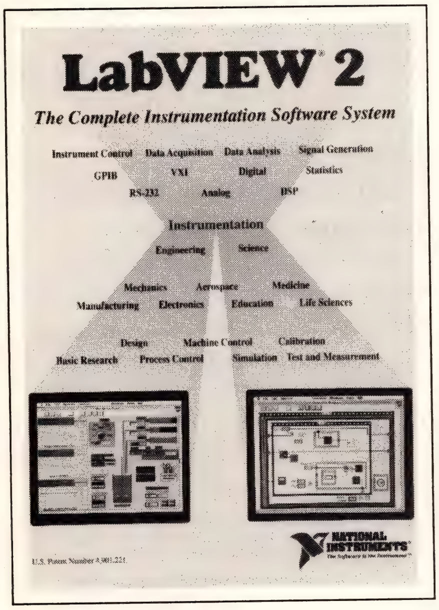
WALL™
Wall Industries, Inc.
5 Watson Brook Rd.• Exeter, NH 03833

CIRCLE NO. 30

800-321-WALL
or 603-778-2300
Fax: 603-778-9797

parallel logic languages. Topics covered are language and operating-system implementations, as well as programming environment design. $39.

Strand Software Technologies Inc, 15220 NW Greenbrier Pkwy, Suite 350, Beaverton, OR 97006.
INQUIRE DIRECT



Booklet On Graphical Programming System

This 8-pg brochure presents the LabView 2 graphical programming system that runs on Macintosh computers. The publication illustrates how block diagrams and front panels are developed and used for data acquisition; instrument control; and data analysis, presentation, and management. It also includes technical-support information and a product-specification sheet.

National Instruments, 6504 Bridge Point Pkwy, Austin, TX 78730. **Circle No. 372**

Data Book Highlights PLDs

The 1990 PAL Device Data Book (PID #10173B) is a complete guide to data sheets and supporting information on programmable logic devices. Containing 800 pgs, the book features military and commercial PLDs. Architecture families include PAL devices, programmable logic sequencers, and field-programmable controllers, as well as field-programmable gate arrays (FPGAs). Data sheets cover more than 60 products, and more than 60 products have been added. More than half of the added products are manufactured using low-power erasable CMOS technology. Topics of articles in the data book include optimal design techniques for high-speed bipolar and CMOS PLDs, transmission-line characteristics, and grounding. The book also provides listings of programmers for the PLDs and third-party design and programming tools for programmable logic. Finally, the book describes the company's Palasm design software and LabPro programmer for low-cost support of company products.

Advanced Micro Devices Inc, Box 3453, Sunnyvale, CA 94088. **Circle No. 373**

Journal On Circuits For Signal Processing

The quarterly technical journal, *Analog Dialogue,* vol 23, no. 4, highlights high-speed pin electronics, the electrical interface between an automatic-test-equipment (ATE) system and each pin of the device under test. This issue discusses ATE design problems and solutions, using a wide selection of high-performance components. Articles deal with an 8-bit 2-channel analog I/O port for position monitoring and control, a monolithic FET-input op amp, and single and dual TTL-compatible comparators. Two regular features are Ask the Applications Engineer, which discusses comparators and their proper use, and Worth Reading, which highlights the National Institute of Standards and Technology's report, *Guidelines for Implementing the New Representations of the Volt and Ohm.* Also included is a summary of recent products for the Component Disk Selection Guide.

Analog Devices, Literature Center, 70 Shawmut Rd, Canton, MA 02021. **Circle No. 374**

Components To Simplify Brush Motor-Drive Design

Application note AN1078/D, *New Components Simplify Brush Motor Control Drive,* describes a variety of components that make brush motor-drive design easier. The document explains how you can combine these components to make practical drive circuits. It considers topologies that control speed in both directions and operate from a single power supply.

Motorola Literature Distribution, Box 20912, Phoenix, AZ 85036. **Circle No. 375**

Volume Explores AC Power Conditioners

The hard-cover book, *AC Power Conditioners: Design and Applications,* is aimed at engineers with little or no experience in power conversion. The volume should provide enough information for such engineers to design equipment that will provide power protection for any situation. The four sections of the book cover power problems, noise and surge reduction, power-line regulation, and blackout protection. The publication deals with actual working circuits. $44.95.

Academic Press Inc, 1250 Sixth Ave, San Diego CA 92101.
INQUIRE DIRECT

App Note On Voltage Regulators

AN32: High Efficiency Linear Regulators explains that linear regulators continue to be used in power supplies because they are easier to use than switching devices, but they have high power dissipation. The note gives advice on how to reduce power dissipation by regulator selection and by circuit design. The note includes circuit designs for a variety of pre- and post-regulator circuits for fixed and variable output supplies, including a design for a 10A regulator having 400 mV of dropout. An appendix offers design advice on selecting a pass element for power-supply design.

Linear Technology Corp, 1630 McCarthy Blvd, Milpitas, CA 95035. **Circle No. 376**

Brochure Discusses Data-Acquisition Software

This pamphlet provides an overview of Superscope software, a data-acquisition and analysis package for the Macintosh computer. The 4-color illustrated brochure directs you to send for the 56-pg catalog that contains product descriptions, compatibility charts, and discussions of sensor interfaces.

GW Instruments Inc, 35 Medford St, Somerville, MA 02143.
Circle No. 377

Guide To Linear Circuits

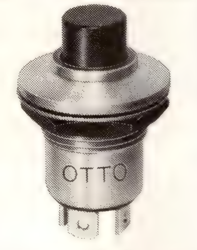
The *New Products Guide* provides a supplement containing products that have been introduced since the *IC Data Book*, Volume 33. Featuring technical abstracts on more than 70 linear products, the guide covers data converters; operational and instrumentation amplifiers; power, isolation, and S/H amplifiers; V/F converters; dc/dc converters; signal conditioning modules; and advanced DSP products. Featured products include ADS807/808 complete 12-bit, 100-kHz sampling ADCs; the low-cost ISO122P 1500V isolation amp; and the PCM1750 dual 18-bit monolithic audio ADC. The guide also tells you how to obtain additional literature and request technical assistance.

Burr-Brown Corp, Box 11400, Tucson, AZ 85734. **Circle No. 378**

More than just the Switch!

Example: A redesigned gear shift improved operator comfort and saved a heavy equipment maker money.

Producing complete switch packages is our specialty. When you select OTTO as your switch supplier, you not only get quality design and manufacturing, you also get our full service value added capability. We will take your requirements from concept, through modeling, field testing, and on to complete product assembly. Most required operations such as plastics molding, stamping and assembly are here, under our control. We consistently demonstrate considerable overall program savings. You will find your project will proceed faster when you place all the responsibility with us.



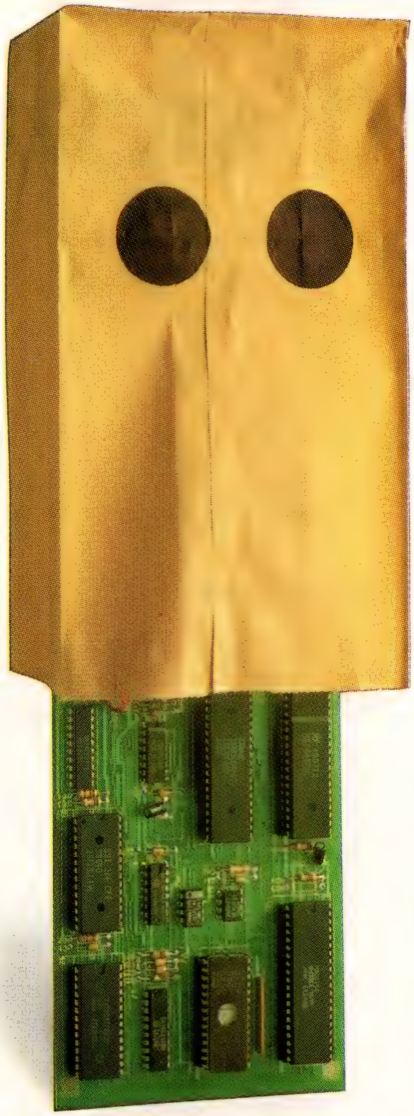
It all started with this: the OTTO P3 sealed pushbutton switch

OTTO® CONTROLS

Call or Fax for our new 44 page Catalog today.

2 E. Main St. • Carpentersville, IL 60110 • Tel: 708/428-7171 • Fax: 708/428-1956

CIRCLE NO. 29



We build anonymous modems for our famous friends

Some of our best OEM customers don't want to be identified; we understand. They're among the world's leading suppliers of computers, intelligent terminals, graphics and engineering workstations and other equipment that requires built-in data communications capability.

These well-known companies have selected UDS as their modem supplier because we provide front-running technology, superb manufacturing capability, unmatched customer support…and discretion. In a word, UDS modems give their products the kind of reliability they like to claim as their own.

UDS has a broad selection of OEM "standard" designs on file; we also offer industry-leading capability for the development of custom boards. Combined, these two approaches have already placed more than 3,000 modem designs into active field service.

If you're one of the big boys — or if you want to solve data-comm problems the way the big boys do — find out what UDS recommends as a cost-effective solution for you. Contact UDS, 5000 Bradford Drive, Huntsville, AL 35805-1993. Telephone 205/430-8000; FAX 205/430-8926.

UDS

MOTOROLA

Created by Dayner/Hall, Inc., Winter Park, Florida

CIRCLE NO. 131

Mixed-signal ASIC

NCR

A lot of designers have mixed feelings about mixed-signal ASICs.

They know they need a higher level of integration on their silicon. But they also know that mixed-signal ASICs can be a challenge. A big one.

For these designers, NCR meets the challenge.

NCR has digital and analog libraries – characterized over all temperatures with functions ranging to 12-bit A/Ds and CMOS processes from 1.5 to sub-micron. With user friendly software tools to put them together.

And, with NCR DesignSim A & D – a comprehensive Analog/Digital System Simulation Package, you may simulate the individual ASIC or the entire system!

NCR also provides off-the-shelf kit parts for in-depth system evaluation, and custom designed cells for special requirements.

NCR can deliver a few prototypes or a few hundred thousand parts all manufactured on the same production line. Assuring continuity in process and quality.

Finally NCR has a mixed-signal test environment created specifically to test Analog/Digital ASICs without compromising either domain.

All this has resulted in NCR being ranked #1 in worldwide cell-based mixed-signal ASIC suppliers*.

And that's why designers who know NCR, don't have mixed feelings about mixed-signal ASICs.

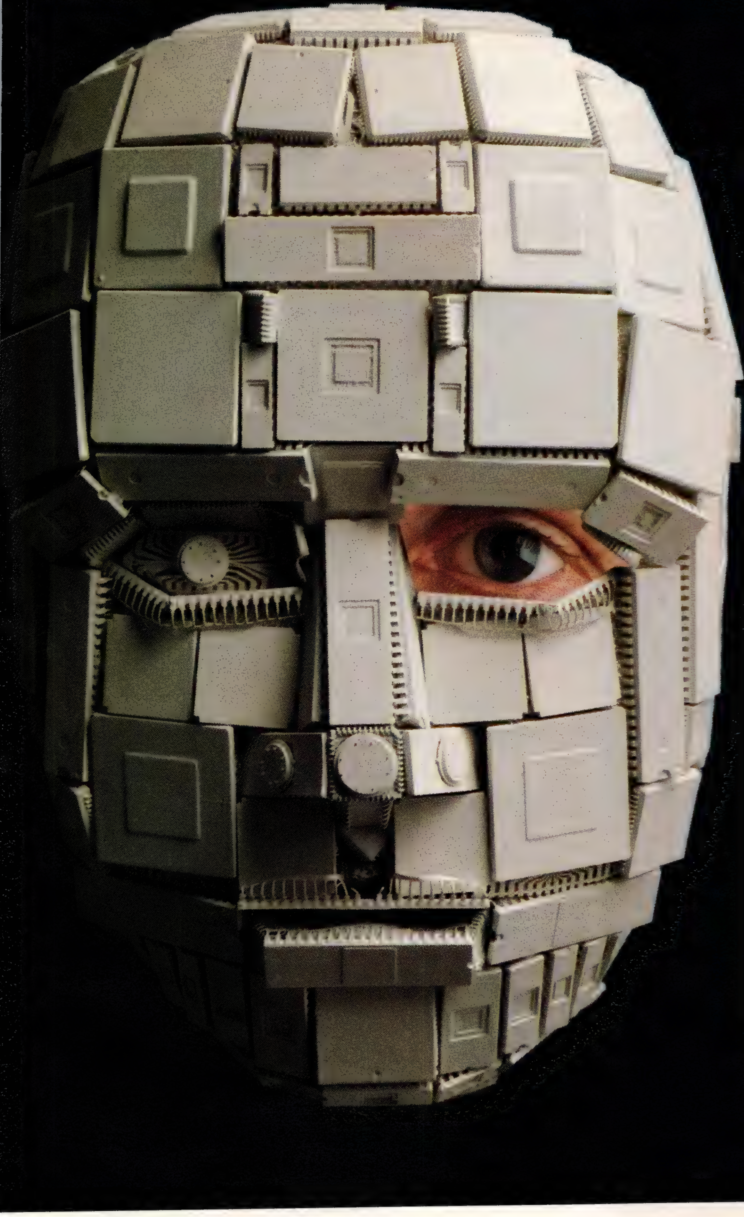
Call 1-800-334-5454 for complete information.

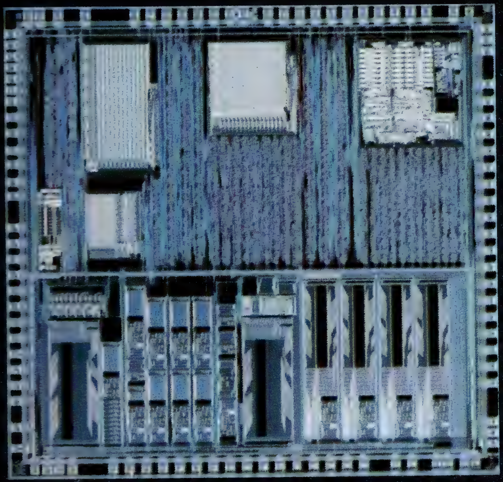
**Integrated Circuit Engineering, 1988/1989*

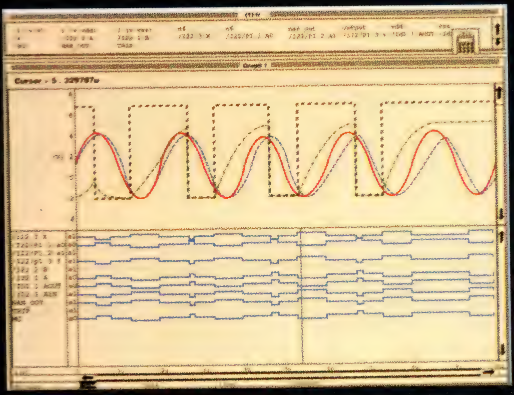
Creating value

Worldwide Sales Headquarters
3130 De La Cruz Boulevard, Suite 209
Santa Clara, California 95054
1-800-334-5454

without mixed feelings





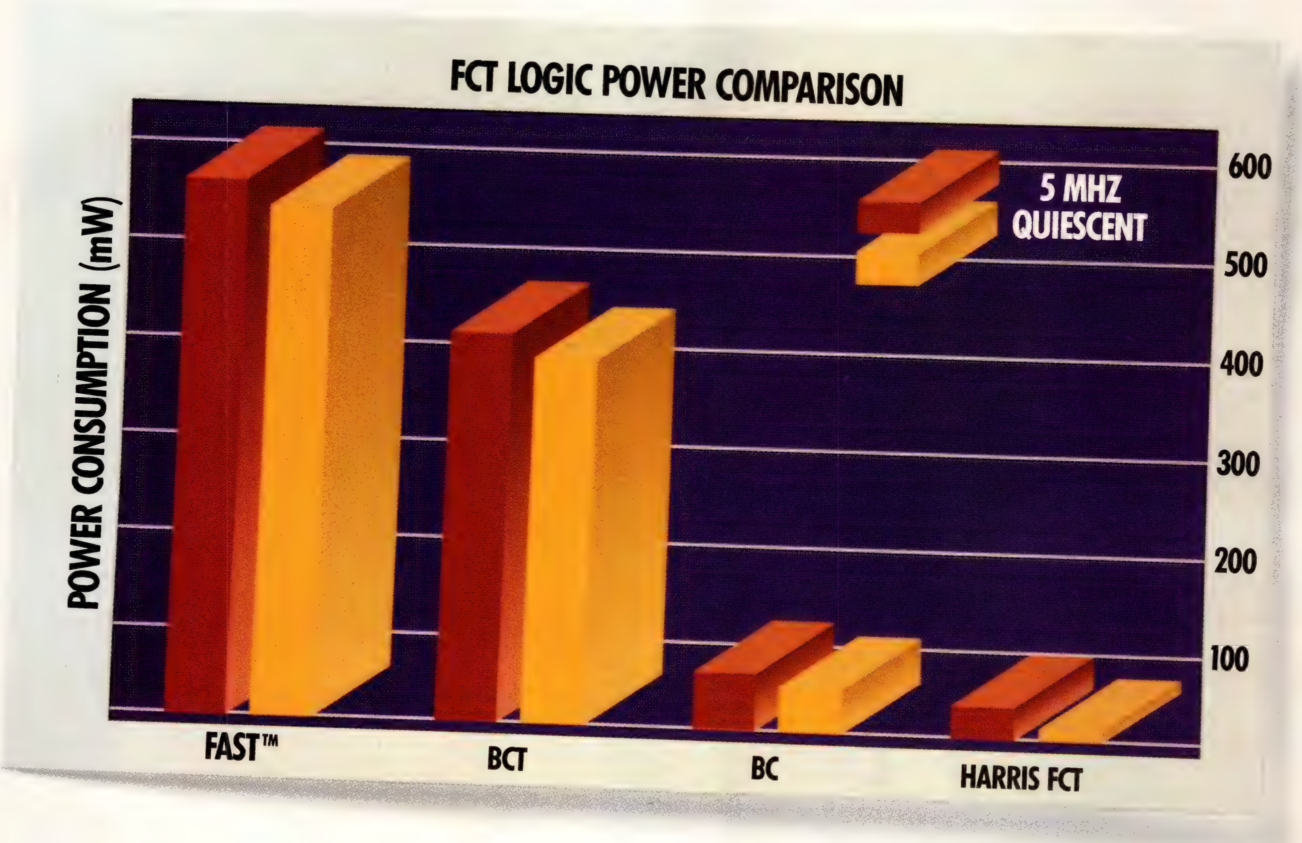


European Sales Headquarters
Gustav-Heinemann-Ring 133
8000 Munchen 83
West Germany
49 89 632202

Asia/Pacific Sales Headquarters
2501 Vicwood Plaza
199 Des Voeux Road
Central Hong Kong
852 859 6044

CIRCLE NO. 144

We're virtually powerless against the competition.

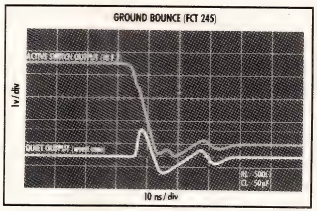


Harris' FCTs Mean High Speed. Not High Power.

When it comes to FCT logic power consumption, less is better. And that's just what Harris' new FCT logic family gives you. Based on our advances in BiCMOS technology, Harris' FCT logic circuits offer you CMOS power consumption at bipolar speeds. With a typical 4.2 nanosecond propagation delay.

Cool Operation.

By reducing power consumption, Harris' FCT logic family generates less heat within your system. Less heat helps increase the reliability of your equipment, along with improving its performance. Noise levels are also lowered, as is ground bounce.



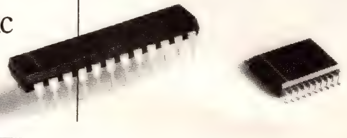
Years of CMOS Innovation.

The new FCT is only the latest advancement in Harris' more powerful, and less power-hungry, CMOS logic.

The new FCT logic family from Harris. Everything you've always wanted in FCT logic. Only less.

For more information on our FCTs, call us at 1-800-4-HARRIS, ext. 1020 (in Canada, 1-800-344-2444, ext. 1020). Or call your local Harris sales office or distributor.

What your vision of the future demands. Today.



HARRIS
SEMICONDUCTOR
HARRIS · RCA · GE · INTERSIL

CIRCLE NO. 133

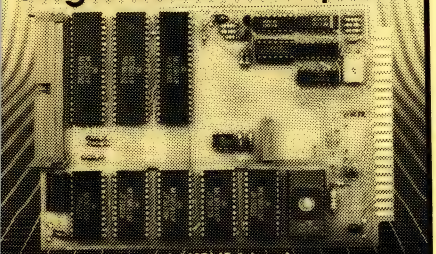
EDN
PRODUCT MART

This advertising is for new and current products.

Please circle Reader Service number for additional information from manufacturers.

$76.50*

Single Board Computer



*500 piece price, model MCL45 (shown)

6800 MPU, serial I/O, parallel I/O, RAM, EPROM, 44-pin 4.5" × 6.5" PCB

EXPANSION MODULES: RAM, EPROM, CMOS RAM/ battery, analog I/O, serial I/O, parallel I/O, counter/ timer, IEEE-488, EPROM programmer, floppy disks, cassette, breadboard, keyboard/display.

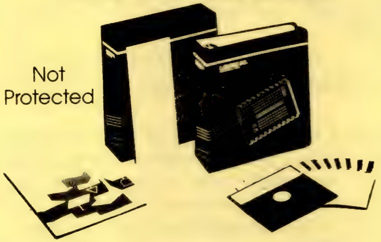
WINTEK

Wintek Corp.
1801 South Street
Lafayette, IN 47904
317-742-8428
(800) 742-6809

CIRCLE NO 325

PAL™/PLD SOFTWARE

Sets The Standard

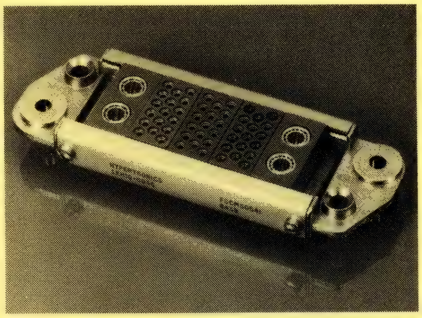


CUPL™ PLD compiler, the most powerful language for state machine logic design, now allows front end design entry with popular schematic capture packages such as OrCAD, P-CAD, Schema or Hi-Wire. CUPL supports all PLDs and carries the most extensive update program. Available on MS-DOS™, Apollo™, Sun™ VAX™ and most UNIX™ based platforms.

LOGICAL DEVICES, INC.

1201 N.W. 65th Place
Ft. Lauderdale, FL 33309
Fax: 305-974-8531
1-800-331-7766

CIRCLE NO 326



PORTABLE DISC DRIVE CONNECTOR

L Series Rack & Panel Connectors provide in excess of 100,000 cycles with excellent electrical repeatability. The rugged blind matable float design and low insertion force contacts provides the performance needed in removable disc drives. Crimp and solder style contacts for 8, 15, 25 and 50 amp use are available. Meets performance requirements of MIL-C-28748A.

HYPERTRONICS CORPORATION
16 Brent Drive, Hudson, MA 01749
(508) 568-0451

CIRCLE NO 327

DS-51 CEIBO

8051 EMULATOR

$950*

INCLUDED IN THE PURCHASE PRICE

- Real-time and transparent In-Circuit Emulator with 64K breakpoints, 64 KByte Internal Data and 64 KByte Internal Code Memory.
- Personality probe for ROMless versions of 8051 μC (8031-2 - etc).
- User software including symbolic debugger, on line assembler and disassembler, PLM and C support, source and listing windows.
- RS-232 Interface Cable and Power Cord.
- User's Manual and Operating Instructions.

AND OF COURSE THE GREAT OPTIONS !!!

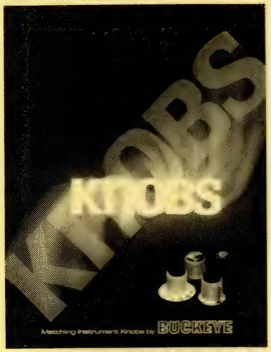
- Trace and Logic Analyzer-32K x 32 - 5 External Testpoints $800*
- EPROM Programmer for 27xxx type memories $250*
- Personality Probe for 8051 μC with Internal Code $500*

For more information call or write to:

USA:	105 Gleason Rd. Lexington MA 02173	Phone Fax	617-863-9927 617-863-9649
Germany:	Krankenhausstr. 12 D-8870 Günzburg	Phone Fax	(082-21) 30023 (082-21) 30462
Hong Kong:	P.O.Box 30719 Causeway Bay	Phone Fax	(852) 5-454341 (852) 5-8541302
Israel:	P.O.Box 2106 Herzelyia 46120	Phone Fax	(972-52) 555387 (972-52) 559170

* US ONLY

CIRCLE NO 328



FREE 26 Page CATALOG with all styles and designs of matching instrument knobs illustrated.

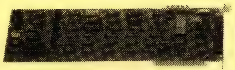
Fax us your specs—we will Fax you a quote...immediately!

Buckeye

555 Marion Road
Columbus, OH 43207

Fax: 614/445-8224 Phone: 614/445-8433

CIRCLE NO 329



LOW COST Data Aquisition Cards for PC/XT/AT

12 Bit A/D & D/A [PCL711S] $295

- **A/D converter**: 8 single-ended channels; Uses **AD574** device; Conversion time is less than **25μsec**; Input range: **±5V**; Software Trigger Mode only.
- **D/A converter**: 1 channel; 12 bit resolution; 0 to **+5/10V** Output Range.
- **Digital I/O**: 16 In/Out(TTLcompatible); External Wiring Terminal Board incl.
- **Utility Routines** and **Demo/Sample Programs** for **BASIC** and **Quick-BASIC**.

12 Bit A/D & D/A [PCL812] $395

- **A/D converter**: 16 single ended inputs; Uses AD574; Conversion time less than 25μsec; Built-in programmable pacer; Input Ranges: ±10V, ±5V, ±1V.
- **D/A converter**: 2 channels; 12 bit resolution; Output Range 0-5V.
- **Digital I/O**:16In/Out(TTLcompatible); **Programmable Counter/Timer** (8254).
- **DMA** and interrupt capability. Utility software and sample program in BASIC.

Fast 12 Bit A/D/A [PCL718] $895

- **A/D converter**: 16 single ended or 8 differential channels; 12 bits resolution; Programmable scan rate; Built-in Interrupt and DMA control circuitry. Conversion speed **60,000 smpls/sec** (standard), **100,000 smpls/sec** (optional).
- Input Ranges:Bipolar : ±10V, ±5V, ±2.5V, ±1V, ±0.5V; Unipolar:10,5,2,1V
- **D/A converter**: 2 channels; Resolution: **12 bits**; Settling time: **5μsec**; ±5V
- **Digital I/O**:16In/Out(TTLcompatible); **Programmable Counter/Timer** (8254).
- **Software:** Utility software for BASIC & QuickBASIC included. Sample prgm. Supported by **LabDAS, ASSYST, LABTECH, UnkeScope.**

6 Channel 12 bit D/A [PCL726] $495

- **Output Ranges**: 0 to +5V, 0 to +10V, ±5V, ±10V, or sink 4-20mA.
- Settling time: **70μS.** Linearity: **±1/2bit.**Voltage output drive capacity: **±5mA.**
- **Digital I/O:** 16 digital input and 16 digital outputs (TTL compatible).

MC / VISA / AMEX *Call today for datasheets!*

B&C MICROSYSTEMS INC.
355 West Olive Ave, Sunnyvale, CA 94086 USA
TEL: (408)730-5511 FAX: (408)730-5521

CIRCLE NO 330

To advertise in Product Mart, call Joanne Dorian, 212/463-6415

PLASMADOT: Dot matrix for graphics as well as text!

Cherry announces PLASMADOT,™ a bright new dot matrix gas plasma display. Designed for high-volume OEM applications ranging from management equipment to information centers. High-brightness pixels and contrast; round, square or rectangular pixel shapes. Full-field dot matrix display ideal for graphics as well as text. Write or call Cherry for details today!

CHERRY®
The Cherry Corporation
Cherry Electrical Products
3600 Sunset Avenue, Waukegan, IL 60087
Phone: 708/360-3500 • Facsimile: 708/360-3566

CIRCLE NO 331

RELIABILITY PREDICTION SOFTWARE

ARE YOUR PRODUCTS RELIABLE?

The RelCalc 2 Software Package predicts the reliability of your system using the part stress procedure of MIL-HDBK-217E, and runs on the IBM PC and full compatibles. Say goodbye to tedious, time consuming, and error prone manual methods! RelCalc 2 is very easy to use, and features menu windows, library functions, global editing for what-if? trials, and clear report formats. Try our Demo Package for $25.

T-CUBED SYSTEMS, 31220 La Baya Drive #110, Westlake Village, CA 91362. (818) 991-0057 • FAX: (818) 991-1281

CIRCLE NO 332

---

32 MEGS OF PORTABLE HARD DISK BACK UP OVER RS232 WITH MS-DOS SOFTWARE DRIVER FOR PCs.

- RS232 INTERFACE
- NO SPECIAL "ADD IN" PC CARDS NEEDED
- NO SPECIAL "BACK UP" SOFTWARE NEEDED
- MULTIPLE PC BACK UP WITH SINGLE EASI-TAPE SYSTEM
- POWER 110/220 VAC OR 12/24 VDC
- PRICE IS $1,295 IN SINGLES, QUANTITY DISCOUNTS AVAILABLE
- OPTIONAL 488, 8 BIT PARALLEL, 485, 422 INTERFACES AVAILABLE FOR USE IN DATA LOGGING APPLICATIONS

28 OTHER SYSTEMS WITH STORAGE FROM 100K TO 42 MEGABYTES

ADPI
ANALOG & DIGITAL PERIPHERALS, INC.
251 South Mulberry St., Troy, Ohio 45373
P.O. Box 499 TWX 810/450-2685
513/339-2241 FAX 513/339-0070

CIRCLE NO 333

WORLD'S SMALLEST

SMT QUARTZ CRYSTALS and CLOCK OSCILLATORS

212-505-4179

- 10kHz-32MHz
- ceramic & metal packages
- hermetically-sealed
- hi-temp mounting
- tape & reel
- thru-hole versions
- shock resistant

FREE CATALOG

MC
MICRO CRYSTAL
35 East 21st Street
New York, N.Y.

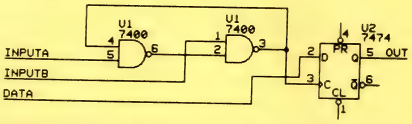
CIRCLE NO 334

NEW SCHEMA III

MOST POWER OF ANY PC SCHEMATIC CAPTURE PACKAGE

Unlimited hierarchies, ASCII input, 7000+ unique parts, library customization, user defined manager, color selections, online HELP, many netlist formats, TIFF, AutoCAD block, & PostScript outputs and much more!

ONLY $495

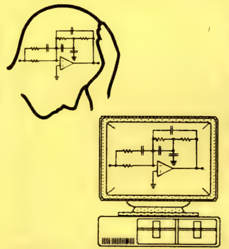


FREE Demo Disk * Free 800 Support
FAX:(214)783-9072 BBS#(214)231-1350

1-800-553-9119

OMATION

CIRCLE NO 335



Software to release your creative genius

ELECTRONIC ENGINEERS CALL FOR YOUR FREE MAC & MSDOS CATALOG

- AC/DC circuit analysis
- Active & passive filter design & analysis
- Engineering graphics
- Signal processing
- Logic simulation
- Root locus analysis
- Microstrip design
- Thermal analysis
- Statistics/ More

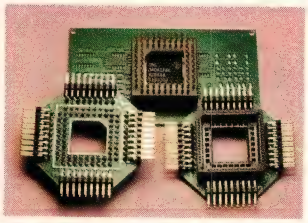
BV Engineering
Professional Software

MasterCard VISA

To order call toll free **1-800-229-0283**
2023 Chicago Ave., Ste. B-13, Riverside, CA 92507

CIRCLE NO 336

PLCC LoClip - PLCC Probe



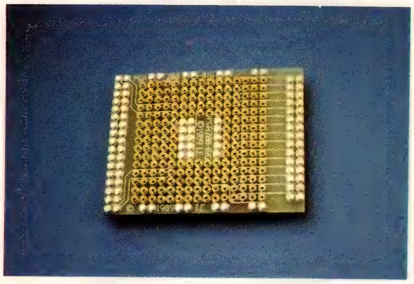
NEW PRODUCT

The **PLCC-LoClipXX** line from Ironwood is a new product line allowing probing of surface mount PLCC's at a **fraction of size** of other clips. The U and L ver. have right angle leads (cable connect or probing). Device heights of 0.75", 0.57", and 0.45" for S, U, and L boards respectively **enable probing of boards in backpanels. Interdevice spacing of 0.10"** allowed. PLCC's from 24 to 84 pins supported. **Kits of 10** with **different sizes/carrying case** available at substantial discount.

IRONWOOD ELECTRONICS
P.O. BOX 21151, ST. PAUL, MN 55121
(612) 431-7025

CIRCLE NO 337

PROTOTYPING ADAPTORS



BY THE HUNDREDS

Our line of **prototyping adaptors** for VLSI devices including **PGA, PLCC, LCC, ZIP, DIP, and Plastic Quad Flatpak** is the most extensive available in the industry. These devices allow easy prototyping of these difficult to handle devices. Pins and sockets used are gold plated and of the highest quality. Parts are available in soldertail or with 3 level wirewrap pins. All types of wirewrap panels are covered.

IRONWOOD ELECTRONICS
P.O. BOX 21151, ST. PAUL, MN 55121
(612) 431-7025

CIRCLE NO 338

IEEE 488

Easiest to use, GUARANTEED!

- IBM PC, PS/2, Macintosh, HP, Sun, DEC
- IEEE device drivers for DOS, UNIX, Lotus 1-2-3, VMS, XENIX & Macintosh
- Menu or icon-driven acquisition software
- IEEE analyzers, expanders, extenders, buffers
- Analog I/O, digital I/O, RS-232, RS-422, SCSI, modem & Centronics converters to IEEE 488

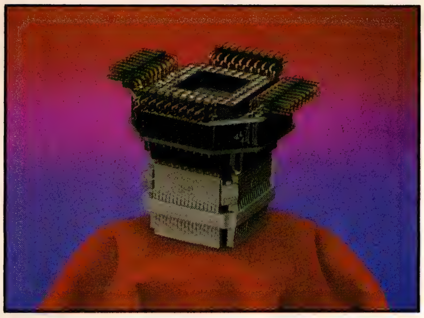
Free Catalog & Demo Disks
(216) 439-4091

IOtech

IOtech • 25971 Cannon Rd. • Cleveland, OH 44146

CIRCLE NO 339

To advertise in Product Mart, call Joanne Dorian, 212/463-6415



PLCC Package Adapter Clips

- QuadClip™ turns your surface-mounted PLCC package into an accessible, pin-grid package for easy emulation.
- Makes it possible to test chips on production boards without un-soldering your PLCC packages.
- Can be attached to packages with up to 84 pins, including the 68000 series chips and 8031-51 chip.
- Custom orders get immediate attention and quick turn-around. For a free catalog, contact:

ET

Emulation Technology, Inc.
2368-B Walsh Ave. Santa Clara, CA 95051
Phone: 408-982-0660 FAX: 408-982-0664

CIRCLE NO 340

OrCAD
Answers the PLD Challenge

OrCAD, makers of the most popular EDA tools in the world, offer incredible power and ease-of-use in **OrCAD/PLD**. Imagine a $495 product that includes testing capabilities, JEDEC or hex output and 7 forms of input including Boolean equations, state machines, truth tables, indexed equations, logic synthesis and schematic entry.

Call for a free demo disk and guide. (503) 690-9881.

OrCAD®

CIRCLE NO 341

8051

PC BASED EMULATORS

- Source Level Debug for PL/M and 'C'
- Source Level trace
- Debug with symbols, not HEX data
- Source Level disassembly with in-line assembler
- Interchangeable probe cards
- Up to 128K emulation memory
- 20 MHz real-time emulation
- Up to 4K trace buffer
- Performance analyzer
- TRUE 8051 Emulation including all I/O ports, idle, power down, DMA, and WatchDog timers at **NO** additional cost
- Breaks set symbolically
- Fully documented
- Serially linked to PC
- OEM supplier to 8051 IC manufacturers
- Unlimited FREE technical support
- From $1495*

MetaLink™...Originators of the PC Based 8051 Emulator

We have more 8051 emulators than anyone in the world: 8031, 8051, 8032, 8052, 8344, 8044, 80C152JA/JB/JC/JD, 83C152JA/JC, 80C452, 80C51FA, 80515, 80535, 80512, 80532, 80513, 80C517, 80C521, 80C541, 80C321, 8053, 8XC154, 8XC451, 8XC552, 8XC562, 8XC652, 8XC751, 8XC752, 80C537, CMOS, EPROMs, OTPs

Call or write for Free demo diskette

1-800-METAICE®

MetaLink® Corporation

MetaLink Corporation P.O. Box 1329, Chandler, AZ 85244-1329
(602)926-0797 FAX: (602)926-1198 TELEX:4998050 MTLNK
*Price is U.S. list

CIRCLE NO 342

Wave Form 20MHz-32K $1290

The WSB-100 Wave Form Synthesizer Board from Quatech has the best set of numbers in the market. With speed to 20MHz and a 32K memory at $1290, it's making waves in more ways than one. The WSB-100 is also a star performer as a digital pulse/word generator with the optional digital module.

Call for our free
PC Interface Handbook
1-800-553-1170

QUATECH

666 Wolf Ledges Parkway
Akron, OH 44311

CIRCLE NO 343

RIBBON-AX™
Near Coax Performance Cable

W.L. Gore has introduced a new brochure on their RIBBON-AX near coax performance cable. This brochure discusses the electrical performance of the cable compared to standard RG coax, the physical characteristics of RIBBON-AX cable, and the testing methods used to analyze and test the product. Two data sheets also accompany the brochure detailing the termination instructions to be used and the design possibilities of RIBBON-AX cable.

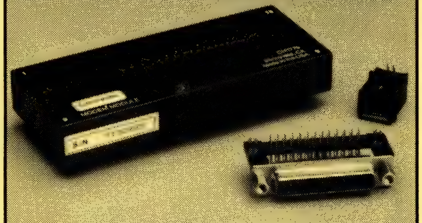
W.L. Gore & Associates
P.O. Box 50690
4747 East Beautiful Lane
Phoenix, AZ 85076-0699
(602) 431-0077

GORE

RIBBON-AX is a trademark of W.L. Gore & Associates, Inc.

CIRCLE NO 344

SUPER LOW COST MODEMS



- 1200, 2400, 4800, 9600 bps
- Standard or Custom Modem Modules or PCBs
- International or Domestic
- FCC Part 68 Approved
- Quick to Market/ Guaranteed Performance

Your Source for Modem Components:

Cermetek microelectronics

Tel: 408-752-5000
Fax: 408-752-5004

Cermetek Microelectronics, Inc.
1308 Borregas Ave. • Sunnyvale, CA 94089

CIRCLE NO 345

Schematic Capture for the Macintosh

DESIGNWORKS

Schematic features Menu-driven, mouse-controlled operations • cut/copy/paste between circuits • right-angle rubberbanding. **Digital simulation** 13-state, event-driven simulation • logic analyzer-style timing window • PLD support. **Libraries** Fully-simulated 7400, 4000, 10K series, PLDs, PROMs and RAMs, non-simulated analog and discrete components • User-definable, simulated custom symbols. **Interfaces** Formats for Douglas CAD/CAM, Cadnetix, Calay, Orcad, Tango, Racal Redac, Spice. • user-definable printers, dot-matrix printers, HP, Houston, Roland pen plotters. **Requirements** Macintosh Plus, SE, II, IIx, IIcx, or IIci.

CALL (604) 669-6343 FOR YOUR FREE DEMO DISK TODAY.

CAPILANO COMPUTING SYSTEMS LTD.

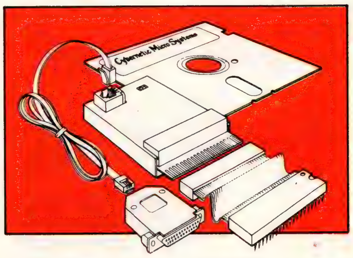
CIRCLE NO 346

LEMO QUALITY CONNECTORS

Self-latching, circular, quick connect-disconnect connectors are available in multi or mixed contact configurations, high voltage, environmentally sealed, fiber optic, fluidic, coaxial, triaxial, thermocouple and plastic.

LEMO USA, INC.
P.O. Box 11488
Santa Rosa, CA 95406
Phone (800) 444-LEMO
FAX 707/578-0869.

CIRCLE NO 347



8051 Emulator - $1250

d^{2}ICE is a low cost, Full Speed, real time 8051 Emulator.. Powerful user interface for Hi-level multi-window source code debugging. Uses IBM-PC COM1/2. No Slots! Portable, fits in shirt pocket. Assembler and test bed included.

Cybernetic Micro Systems
PO Box 3000 • San Gregorio CA 94074
Ph: (415) 726-3000 • Fax: (415) 726-3003

CIRCLE NO 348

To advertise in Product Mart, call Joanne Dorian, 212/463-6415

WANTED

LAS Bug #880285

Timing Error

Exterminate him with the 8 ns resolution the Logic Analysis System

4k to 64k memory depth
16 level triggering with pass counter
40 to 320 channels
A complete Logic Analyzer on a Card
Interactive software under Microsoft™ Windows
Source code in C for automatic testing

BITWISE
DESIGNS, INC.

701 River Street
Troy, NY 12180
(800) 367-5906
(518) 274-0755
FAX (518) 274-0764

CIRCLE NO 349

More Than 100,000 Parts —*J.I.T.*

Hex Jack Screws, Standoffs of all types, Captive Screws, Cabinet Handles and dozens of other types of electronic hardware are on the shelf ready to ship. You can be sure of consistent quality of American-made parts. If you need special hardware, we'll custom manufacture it to your prints. Write or call today for our 160-page catalog.

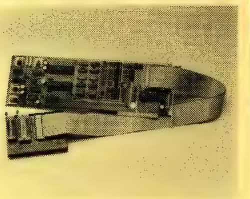
RAF Electronic Hardware,
95 Silvermine Road, Seymour, CT 06483.
(203) 888-2133, FAX (203) 888-9860

CIRCLE NO 350

Almost Universal Device

PROGRAMMER

PAL
GAL
EPROM
EEPROM
PROM
87xxx...



$475

LATTICE - MMI - INTEL - TI
AMD - DALLAS - ALTERA

5ns PALs
2 Meg EPROMs

Parts added at your request.

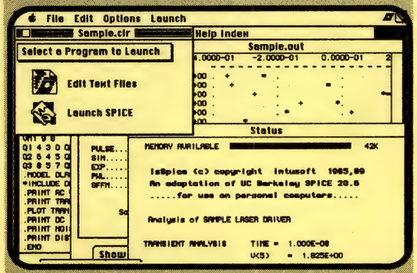
FREE software updates on BBS.
Powerful menu driven software.

CATALYST - XICOR
WSI - ICT - and MORE

Call - (201) 994-6669
Link Computer Graphics, Inc.
4 Sparrow Dr., Livingston, NJ 07039 FAX:994-0730

CIRCLE NO 751

Analog Circuit Simulation
SPICE FOR THE MACINTOSH



```
MEMORY AVAILABLE                42K

IsSpice (c) copyright  intusoft  1985,89
An adaptation of UC Berkeley SPICE 2G.6
.....for use on personal computers.....

Analysis of SAMPLE LASER DRIVER

TRANSIENT ANALYSIS      TIME =  1.000E-08
                        V(5)  =  1.825E+00
```

***Intusoft* introduces the NEW !! IsSPICE/MAC,**
The only Spice program to run on all Macintoshes (Plus, SE, SE/30 and Mac II) in as little as 1 megabyte of RAM. The simulatable circuit size is only limited by the amount of RAM. Coprocessor ($210) and Non-coprocessor ($95) versions are available. Also available is PRESPICE/MAC ($175) which contains extensive model libraries, the IsSPICE netlist editor and ICAPS, an easy to use menu system especially adapted for the MAC environment.

P.O. Box 6607
San Pedro, CA
90734-6607

intusoft

(213) 833-0710
30 Day Money Back Guarantee

Macintosh is a registered trademark of Apple Computer

CIRCLE NO 752

LISTEN TO WHAT OUR USERS SAY:

TESS
COMMUNICATIONS BLOCK DIAGRAM SIMULATION FOR PCs

"Eats SPICE for breakfast!..very nicely done" - G.W., Iowa

"totally amazed at how powerful it is!" - G.P., Illinois

"really like the simplicity of using the thing" - W.F., Texas

"It's a beautiful program" - R.N. from Maryland

"The program is proving very useful in designing and refining a voice inversion scrambler. Again thanks for a fine product" - R.K., Virginia

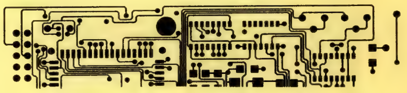
"It's an impressive program" - T.J. from Texas

"We're enjoying the TESOFT tools very much in our modem design project. My engineers say that it's easy to use" - K.D., Utah

WHAT MORE CAN WE ADD? CALL FOR A DEMO DISK!
TESOFT 404-751-9785 PO BOX 305 Roswell GA 30077

CIRCLE NO 753

PLOT ANY CAD FILES



GERBER, HPGL, DMPL or DXF data.

We do fine-line photoplotting on film or glass and can make prototype or production PC boards from your data files. Send us your Gerber or pen plot files on disk, magtape or telephone modem. GET A NO-CHARGE ESTIMATE IN 24 HOURS.
Layout and PC design, too .

COUPONS FOR CAD

MIL-STD-275E (ANSI/IPC-D-319) coupons are available on disk as Gerber-format data for inclusion in your PC CAD files or we can add them to your Gerber data file before plotting. Coupons are also available on registered, pre-punched films.

Send for **FREE** literature or give us a call.

J. NELSON GRAPHICS

23500 Mercantile Road
Cleveland, Ohio 44122

(216) 464-0200

CIRCLE NO 754

There is a Difference.
Lifetime Free Updates

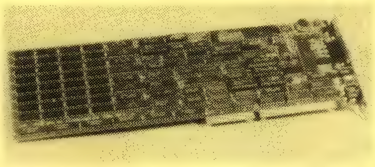
EP-1140
$895

A programmer is not just another programmer. That is why BP Microsystems is commited to bringing our customers the highest quality programmers at an affordable price. This commitment is evident in our EP-1140 E/EPROM programmer supporting thousands of 24-, 28-, 32- and 40 pin devices. A 32-pin model, EP-1132, is available also for $695. And, all of our programmers include future chip support at no charge and an unconditional money back guarantee.

BP MICROSYSTEMS
1-800-225-2102
(713) 461-9430

CIRCLE NO 755

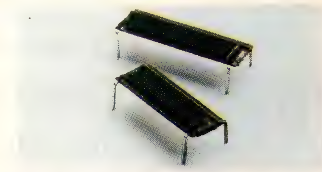
HIGH RESOLUTION FRAME GRABBER



SILICON VIDEO MUX is a single-board frame grabber that provides the PC AT with an interface to high-bandwidth, high-resolution video sources. Up to 8000 pixels per line and 1020 lines per field are supported. An adaptable timing generator allows digitization from line-scan and area-scan devices, as well as from medical equipment and videotape players.

EPIX Inc.
310 Anthony Trail
Northbrook, IL 60062
708-498-4002

CIRCLE NO 756



IMPROVE BOARD PERFORMANCE

MICRO/Q 1000 capacitors can be retrofitted to solve noise problems on existing boards. Because MICRO/Q 1000 caps share mounting holes with existing IC pins, no board redesign is required. Effective decoupling becomes a matter of adding one insertion step.

Rogers Corp., 2400 S. Roosevelt St., Tempe, AZ 85282. 602/967-0624

CIRCLE NO 757

To advertise in Product Mart, call Joanne Dorian, 212/463-6415

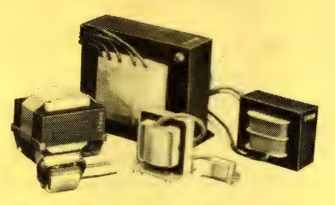
X.25 SDLC
QLLC HDLC
ADCCP PAD

- C source code
- ROM-able
- Full porting provided
- No OS required

GCOM, Inc.
41 E. University
Champaign IL 61820
(217) 352-4266

Specialists in Computer Communications
FAX 217-352-2215

CIRCLE NO 758



Transformers as innovative as your designs

52-page full color catalog provides descriptions, illustrations and complete specifications on thousands of standard off-the-shelf transformers, power supplies, power conversion and AC-DC designs. Also covered is MagneTek Triad's custom design service which has designed and manufactured thousands of custom transformers, from small switches to large ferro-resonant models.

For more information, write MagneTek Triad
1124 E. Franklin St., Huntington, IN 46750
or phone (219) 356-7100.

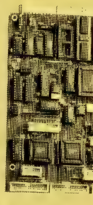
MagneTek

CIRCLE NO 759

Control the World!

Everything you need to setup and run an embedded data acquisition and control system on a single card. The SBS–2300 integrates industrial control, operator interface, communications and operating system.

CAMBASIC II multitasking language supports all hardware. Built–in, single step debugger. Turn your IBM PC into program development workstation with PC SmartLINK.



- 10 analog I/O, 12–bit resolution
- 48 parallel I/O lines
- Keypad port
- 2 programmable serial ports
- EPROM & EEPROM programmers
- Real time clock
- Drives Opto 22 racks
- Network up to 32 systems

Call 303–430–1500

OCTAGON SYSTEM CORPORATION
6510 W. 91st Avenue
Westminster, CO 80005

CIRCLE NO 760

FREE Catalog of Books for Engineering Professionals

These books will help you work smarter, faster, and better.

Topics include: surface mount technology, DRAM design, ISDN design, AC power conditioners, software, hardware, busses, integrated circuits, error-control, power switching supplies, voltage regulators, ASICs, and more—all written with an eye to *practical* applications!

Call 1-619-699-6400 or write for your free catalog TODAY!

Academic Press
Harcourt Brace Jovanovich, Publishers
Book Marketing Dept. #30050
1250 Sixth Ave., San Diego, CA 92101

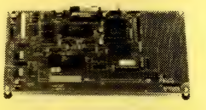
©1990 by Academic Press, Inc. All Rights Reserved. KL/MJD #30050

CIRCLE NO 761

ZWORLD
ENGINEERING

C-Programmable

Single Board Computer



Write large C programs in hours using the efficient Dynamic C programming system with the SBC100 single board computer.

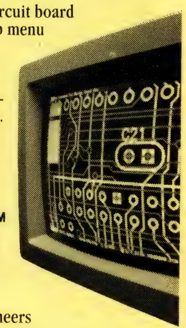
Specifications: Z180/HD64180 processor with 9.216 mhz clock. Serial and parallel ports. iSBX connectors. Battery backed RAM. EPROM. Watchdog timer. Power fail detect. 20-IC prototyping area. Time-date clock. Wall transformer. LED display. Price $395.00.

Z-World Engineering
1340 Covell Blvd. • Davis, CA 95616
(916) 753-3722 • Fax: (916) 753-5141

CIRCLE NO 762

Again, "Best Value" in PCB Design.

Tango sets the pace in PC-based circuit board design with an easy-to-use, pop-up menu interface and powerful features including: 1 mil resolution; full SMT support; DRC; PostScript™ output; fast, high-completion auto-routers; and photoplot previewing. Configure your personal PCB design station from our selection of entry-level and expert tools, starting at just $595.



Tango™

For the second year in a row, engineers have rated Tango the "Best Value" in PCB design at CAD Showdown '90. Rich functionality, one year's updates, free tech support and BBS, plus our 30-day guarantee. Call today.

FREE EVALUATION PACKAGE
800 433-7801 619 554-1000 619 554-1019 Fax

ACCEL™ Technologies ■ 6825 Flanders Drive ■ San Diego, CA 92121 USA
International prices may vary. Contact us for the distributor nearest you.

CIRCLE NO 763

Now, you can afford the high precision you really need.

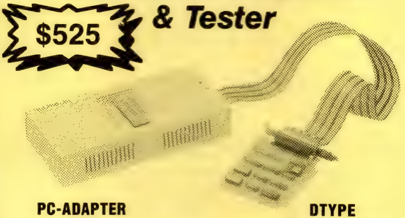
With new YSI Precision Machine-Insertable Thermistors. Tape and reel packaging reduces manufacturing costs and YSI precision gives you the edge in circuit accuracy and reliability. Call 800 343-4357 for information. In Ohio, call 513 767-7241.

YSI Incorporated
Yellow Springs, Ohio 45387 USA

CIRCLE NO 764

EXPRO-40 PC-Based Universal Device Programmer & Tester

$525



PC-ADAPTER CARD

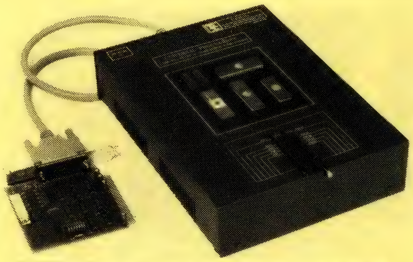
DTYPE 37 PINS CABLE

8 SOFTWARES AVAILABLE FOR POPULAR DEVICE PROGRAMMING

EPROM:NMOS or CMOS EEPROM:2816, 17A, 64A, 256A...
BPROM: From 32x 8 to 4096 x 8 Bipolar PROM MMI, NS, Signetics, TI, AMD, Motorola, Harris, Cypress MPU 8748: 8748, 48H, 49H, 41A, 42H, 41AH, 42AH, 48AH, 49AH
MPU 8751:8751/H, 52/H, 44/H, 51BH, 52BH, C51, C252
PAL, EPLD, GAL, CMOS PAL: MMI, NS, TI, AMD, Cypress, Lattice, 16R8, 20V8, 20L10, 22V10, 22G10, 16V8, 20V8.
IC Tester: 74xx, 40xx, 45xx, DRAM

Songtech International, Inc.
44061 So. Grimmer Blvd., Fremont, CA 94538
Tel: (415) 770-9051 **Fax: (415) 770-9060**

CIRCLE NO 765



PC BASED UNIVERSAL DEVICE PROGRAMMER $695/895

- Programs **EE/EPROMs, PALs, GALs, EPLDs, MICROs, BIPOLARs, PEELs.**
- Software driven pin drivers. **D/A generated** programming voltages (8 bit DACs used to generate voltages from **5-25V** with **0.1V resolution** for all 40 pins)
- **Upgradeable for virtually any future programmable devices up to 40 pins.**
- Self subsistent operation. No additional modules or plug-in adapters required.
- Includes user friendly **MEMORY BUFFER FULL SCREEN EDITOR.** Commands include: Fill, Move, Insert, Delete, Search. ASCII or HEX entry.
- Friendly Menu-Driven interface. **Device selection by P/N and manufacturer.**
- Supports **8/16/32** bit data word formats.
- Programming algorithm:**Normal, Intelligent I&II, Quick Pulse Programming.**
- Verify operation performed at normal & worst case operating voltage
- **Functional test:** JEDEC standard functional testing for logic devices. TTL Logic functional test for 74xx/54xx series devices.
- File formats accepted: **JEDEC (full), JEDEC (kernal), Straight Hex, MOS Technology, Motorola Hex, Intel Hex, Tektronix Hex.**
- Customer support via voice line, fax & dedicated BBS. **Full 1 year warranty.**
- **Base price $695** includes Interface card, cable, Memory/Micro/Bipolar library and 1 year free updates. **$895** with additional **Logic Device Library.**
- **Library updates can be received via floppy or Customer Support BBS.**

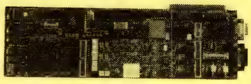
MC / VISA / AMEX *Call today for datasheets!*

B&C MICROSYSTEMS INC.
355 West Olive Ave, Sunnyvale, CA 94086 USA
TEL:(408)730-5511 FAX: (408)730-5521

CIRCLE NO 766

To advertise in Product Mart, call Joanne Dorian, 212/463-6415

TLX01A inserts a telex in your PC



Telex interface with double or simple current (V11, V24/28) • Processor Z180 • Battery backup RAM memory • 2 auxiliary serial ports • PC-AT-XT, PS/2 30 or compatibles • Complete with communication software • Manufacturing license available.

EXOR, P.O. Box 548, West Chester, OH 45069, USA. Fax: 513-777-4817.
Phone: 513-777-0570.

EXOR
Electronic R&D

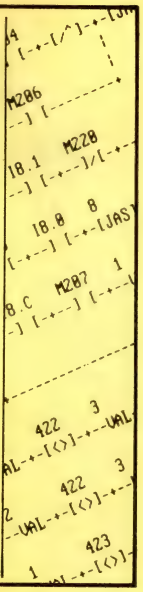
CIRCLE NO 767

µPLC software tools

Powerful software tools convert any µP-80XX, 68XX, Z80, and more—into a PLC and transform MS-DOS PCs into programming peripherals. Complete and efficient. Written in C, integrate with external programs. Available in source code. No royalties. Request free catalog.

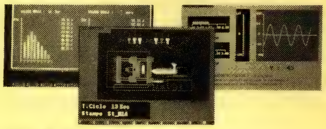
EXOR, P.O. Box 548, West Chester, OH 45069, USA. Fax: 513-777-4817.
Phone: 513-777-0570.

EXOR
Electronic R&D



CIRCLE NO 768

I.A.B., Industrial Applications Builder



Turns PC into DAC system

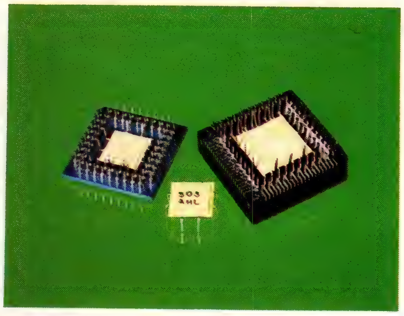
Powerful SW tool kit helps you build IBM PC-based data acquisition and control systems for process and machine applications. You get screen builders, scaling, conditioning, alarms, timing tables, statistics, and more. Flexible, debugged and reliable. Low cost. Available in source code. No royalties. Request free catalog.

EXOR, P.O. Box 548, West Chester, OH 45069, USA. Fax: 513-777-4817.
Phone: 513-777-0570.

EXOR
Electronic R&D

CIRCLE NO 769

STOP NOISE IN PGA, LCC PACKAGES



MICRO/Q 3000 decoupling capacitors stop low-inductance, high-frequency noise for PGA, LCC packages on complex board layouts. Fit them neatly under PGA or LCC sockets, use no extra board space. Choose from many pinout configurations. **Rogers Corp.**, 2400 S. Roosevelt St., Tempe, AZ 85282. 602/967-0624.

CIRCLE NO 770

New EPROM Programmer

At $495, Wintek's Universal EPROM Programmer is a low-cost and versatile tool for programming most industry-standard EPROMs (2716-27256). Since it can operate with an IBM PC, as well as stand alone, the Programmer is ideal for use with PC-based microcomputer development software. Credit cards are welcome.

Wintek Corporation
1801 South St., Lafayette, IN 47904
(800) 742-6809 or (317) 742-8428

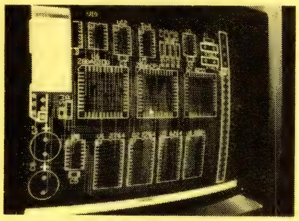
CIRCLE NO 771

HANDHELD 2.4GHz 10 DIGIT LCD UNIVERSAL COUNTER TIMER

Direct counts over 150 MHz
Switched prescalers for max resolution over 2.4GHz
Super sensitive for antenna pick-up
16 segment RF input level bargraph
Measures frequency, period, time interval, ratio and average 4 gate times
120 segment LCD with complete annunciators
Extruded aluminum enclosure with field installable NiCads
10MHz TCXO timebase, optional precision TCXO
UTC 3000 is only $375
Frequency only Model 2600H is $325

OPTOELECTRONICS INC.
5821 NE 14th AVE.,
FT. LAUDERDALE, FL 33334
(800) 327-5912 FL(305) 771-2050

CIRCLE NO 772



Why Do Designers Choose Protel ?

Protel gets the job done !

Professional Quality CAD Tools

Protel offers a full suite of PC-based high-performance PCB design tools with easy-to-use & consistent user interfaces, free tech & EMS support, BBS and 30-day money-back guarantee.

Schematic	**$495**
Popular precision digital and analog schematic design.	
Autotrax	**$1295**
Complete PCB layout with automatic placement & routing for both through-hole and SMD designs. Supports standard printing/plotting formats and up to 4MB EMS	
Traxstar	**$1495**
Powerful multi-layer rip-up and re-try autorouter. Handles over 700 ICs and a board of up to 20x32 inches.	
Traxview	**$695**
Full-featured interactive Gerber viewer and editor with automatic panelization for multiple Gerber files.	

Before you invest in a PCB design product tomorrow. Call toll free (800) 544-4186 for one of our free demo-disks today.
in CA, HI, AK, or Canada, call: (408) 437-7771

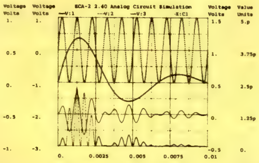
Protel Technology Inc.
50 Airport Parkway (408) 437-7771
San Jose, CA 95110 fax (408) 437-4913

Dealer Inquiries Welcome

Protel Technology

CIRCLE NO 773

Interactive/Real-Time



Analog Circuit Simulation

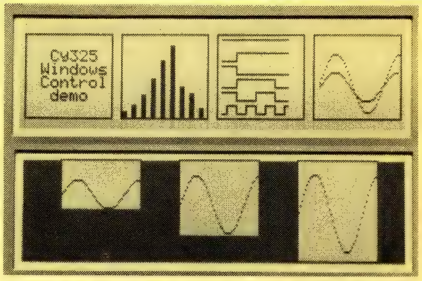
ECA-2 Electronic Circuit Analysis offers the best MonteCarlo and Worst-Case analyses with the capability to concurrently plot random samples or Min/Max/Nominal values.

• AC, DC, Transient, Fourier, and Temperature Analysis • Interactive or batch modes • Full nonlinear simulator • Sine, Pulse, PWL, SFFM, and Exponential generators • IBM PC/Mac/SUN • Multiple plots • On-line real time graphics – **2 to 50 times faster than SPICE** • Over 500 nodes • Advanced component parameters • Component Sweeping • Full editing, built-in or external • Detailed 525 page manual

Call for FREE DEMO!

Tatum Labs, Inc.
3917 Research Park Dr. B-1, Ann Arbor, MI 48108
313-663-8810

CIRCLE NO 774



LCD WINDOWS CONTROLLER

The CY325 supports LCDs up to 128x240 pixels (16x40 char) with easy-to-use high-level commands and Parallel or Serial interface to host computer. The 256 built-in windows (or make your own) support window-relative text, graphics, plotting, bargraphs, waveforms, scroll/wrap/clip, etc. Read from an A/D and Write into Window! Separate text and graphic planes can be written or erased in any window. Eight pins support a variety of functions (soft-keys, waveforms) or can be used for GP I/O. Icons or special fonts can be user defined. Giant character mode, etc. Save months of design time with the CY325. $75 CMOS $20/1000s.

Cybernetic Micro Systems
PO Box 3000 • San Gregorio CA 94074
Ph: (415) 726-3000 • Fax: (415) 726-3003

CIRCLE NO 775

To advertise in Product Mart, call Joanne Dorian, 212/463-6415

For Results Across the Board

The Answer is NEPCON East '90

It's that simple. NEPCON East '90 is the only east coast event that offers all phases of the electronic manufacturing process. One place one time. To make Design For Manufacturability (DFM) real. It's what you and your production team are striving for. In Conference and Exhibits, the answers are at NEPCON East '90. Whether you're involved in circuit design, systems packaging, circuit board fabrication, assembly, through production, test and inspection—learn the newest technology advancements and see the latest equipment, demonstrated at NEPCON East '90. To achieve DFM. To stay competitive in today's electronic manufacturing marketplace. The answer is NEPCON East '90.

NATIONAL ELECTRONIC PACKAGING AND PRODUCTION CONFERENCE
NEPCON
EAST '90

Exhibition: June 12–14, 1990
Conference: June 11–14, 1990
World Trade Center
Bayside Exposition Center
Boston, Massachusetts

ACT NOW—Clip and mail this coupon today to receive your conference and exhibition registration information.

EDN051090

Clip and mail to:
NEPCON East '90 Cahners Exposition Group
1350 East Touhy, P. O. Box 5060, Des Plaines, IL 60017-5060

Please send me pre-registration materials for NEPCON East '90.

Name ____________________
Title ____________________
Company ____________________
Address ____________________
City __________ State ______ Zip ______
Country ____________________
My company is interested in exhibiting at future NEPCON events.
Call me at: ____________________

Please feel free to contact us for additional information: NEPCON East '90, c/o Cahners Exposition Group, phone (708) 299-9311, or FAX (708) 635-1571.

D2

CIRCLE NO. 134

A Member of
Reed Exhibition Companies

©Reed Publishing (U.S.A.) Inc., 1990

BUCHANAN® electronic connectors give you more sizes, more shapes, more options.

Including the lowest cost two-piece connector.

SSB4

- Combines screw termination and plug-in convenience.
- Simultaneous connection of multiple circuits.

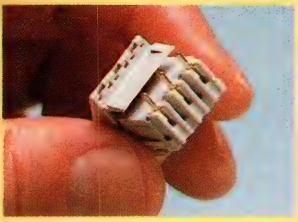
BUCHANAN electronic connectors give you the industry's widest range of sizes, shapes and connection options to choose from. All with the BUCHANAN reliability and quality you've come to expect. BUCHANAN Series SSB4/5 connectors with 5mm and 10mm centerlines meet or exceed all industry standards.

When it comes to connecting discrete wires to electronic circuitry on PC boards, BUCHANAN gives you the lowest applied cost and fastest delivery. No special tools or skills are needed for field wiring — all you need is a screwdriver. That means minimal installation and service times.

Factory inventory has been doubled to meet your needs. And most models of BUCHANAN electronic connectors are in stock at most distributors. Or they can be custom designed with various pin lengths, mounting options and colors for special applications.

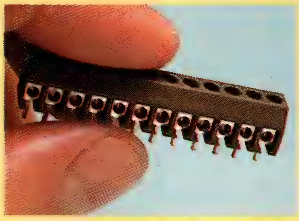
For all the technical information on these connectors with increased contact density and wide application flexibility, send for Designer's Guide I/0-100.

Gold-plated contacts.



- All BUCHANAN connectors available with gold-plated contacts if your application requires it.

Smallest screw-dedicated connector on the market.



Series SMB

- 3.5mm circuit spacing.
- Choice of horizontal or vertical entry.
- 7+ circuits per inch.

amerace INDUSTRIAL ELECTRICAL PRODUCTS

AMERACE CORPORATION
INDUSTRIAL ELECTRICAL PRODUCTS
530 W. MT. PLEASANT AVENUE
LIVINGSTON, NJ 07039-1790
(201) 992-8400
TELEX: 13-8403 • FAX: 201-992-9416

BUCHANAN®

CIRCLE NO. 135

CAREER OPPORTUNITIES

EDN Magazine Edition News Edition

1990 Recruitment Editorial Calendar

Issue	Issue Date	Ad Deadline	Editorial Emphasis
Magazine Edition	June 7	May 17	Software, Design Tools, Microprocessor I/O Chips, μP Support Chip Directory
News Edition	June 14	May 24	Peripherals/Input Devices, Software, Special Supplement: EDA
Magazine Edition	June 21	May 31	Computer-Aided Engineering, Computers & Peripherals, Power Semiconductors, Semicustom ICs/ASICs
News Edition	June 28	June 8	ICs/RISC/Microprocessors, Image Processing, Regional Profile: Oregon & Washington
Magazine Edition	July 5	June 14	Product Showcase—Volume I: Hardware & Interconnect, Power Sources, ICs & Semiconductors, Software
News Edition	July 12	June 21	Analog/Communication ICs, ASICs, Special Supplement: Automotive Electronics, Regional Profile: Washington, D.C.
Magazine Edition	July 19	June 28	Product Showcase—Volume II: CAE/ASICs, Computers & Peripherals, Components, Test & Measurement
Magazine Edition	Aug. 2	July 12	Digital ICs/Microprocessors, Computer-Aided Engineering, Computers & Peripherals, Test & Measurement, Technical Article Database
News Edition	Aug. 9	July 20	CAE/Software, Aerospace, Special Supplement: Defense
Magazine Edition	Aug. 20	July 30	Military Special Issue, Vision/Image Systems, ICs & Semiconductors, Memory Technology, Software
News Edition	Aug. 23	Aug. 3	Electromechanical, Opportunities in Non-EOEM, Regional Profile: New Mexico, Arizona
Magazine Edition	Sept. 3	Aug. 13	ASICs Special Issue—Semicustom ICs, Computer-Aided Engineering, Digital Components, ICs & Semiconductors
News Edition	Sept. 6	Aug. 17	CAE/Software, CASE/CAE, Special Supplement: DSP
Magazine Edition	Sept. 17	Aug. 27	System Software, Computer-Aided Engineering, Analog ICs, Digital ICs
News Edition	Sept. 20	Aug. 30	ICs/Non-volatile Memory, Fiber-Optics, Regional Profile: Georgia, N. Carolina & Alabama
Magazine Edition	Oct. 1	Sept. 10	Computer Boards, Analog ICs, Digital ICs, Test & Measurement
News Edition	Oct. 4	Sept. 14	ICs/LAN Chips/Microprocessors, AI/Expert Systems, Special Supplement: Instruments
Magazine Edition	Oct. 11	Sept. 20	Analog ICs, Computer-Aided Engineering, DSP IC Directory, Displays, International Technology Update
News Edition	Oct. 18	Sept. 28	CAE/Hardware, Datacom, Regional Profile: Idaho, Colorado, Utah
Magazine Edition	Oct. 25	Oct. 4	Test & Measurement Special Issue—Digital Instruments, Computers & Peripherals, ICs & Semiconductors, System Software
Magazine Edition	Nov. 8	Oct. 18	Signal Processing, Computer-Aided Engineering, Computers & Peripherals, Software, Wescon Show Issue
News Edition	Nov. 15	Oct. 26	Displays, Defense, Special Supplement: Interconnect
Magazine Edition	Nov. 22	Nov. 1	17th Annual Microprocessor Directory, ICs & Semiconductors, Test & Measurement, Workstations

Call today for information on Recruitment Advertising:

East Coast: Janet O. Penn (201) 228-8610
West Coast: Nancy Olbers (603) 436-7565
National: Roberta Renard (201) 228-8602

EDN Databank

Professional Profile

Announcing a new placement service for professional engineers!

To help you advance your career. Placement Services, Ltd. has formed the EDN Databank. What is the Databank? It is a computerized system of matching qualified candidates with positions that meet the applicant's professional needs and desires. What are the advantages of this new service?

- **It's absolutely free. There are no fees or charges.**
- **The computer never forgets. When your type of job comes up, it remembers you're qualified.**
- **Service is nationwide. You'll be considered for openings across the U.S. by PSL and it's affiliated offices.**
- **Your identity is protected. Your resume is carefully screened to be sure it will not be sent to your company or parent organization.**
- **Your background and career objectives will periodically be reviewed with you by a PSL professional placement person.**

We hope you're happy in your current position. At the same time, chances are there is an ideal job you'd prefer if you knew about it.

That's why it makes sense for you to register with the EDN Databank. To do so, just mail the completed form below, along with a copy of your resume, to: Placement Services, Ltd., Inc.

IDENTITY

Name ____________________

Home Address: ____________________

City ____________ State: ____________ Zip: ________

Home Phone (include area code): ____________________

PRESENT OR MOST RECENT EMPLOYER

Parent Company ____________________

Your division or subsidiary: ____________________

Location (City, State) ____________________

Business Phone if O.K. to use: ____________________

EDUCATION

Degrees (List)	Major Field	GPA	Year Degree Earned	College or University

POSITION DESIRED

____

EXPERIENCE

Present or Most Recent Position From: To: Title:

Duties and Accomplishments: Industry of Current Employer:

____

____

____

Reason for Change: ____________________

PREVIOUS POSITION:

Job Title: ____________________

Employer: ____________ From: ________ To: ________ City: ____________ State: ____________

Division: ____________ Type of Industry: ____________ Salary: ____________

Duties and Accomplishments: ____________________

COMPENSATION/PERSONAL INFORMATION

Years Experience	Base Salary	Commission	Bonus	Total Compensation	Asking Compensation	Min. Compensation

Date Available	I Will Travel ☐ Light ☐ Moderate ☐ Heavy	☐ I own my home. How long? ________ I rent my home/apt. ☐
☐ Employed ☐ Self-Employed ☐ Unemployed	☐ Married ☐ Single	Height ________ Weight ________
Level of Security Clearance	☐ U.S. Citizen ☐ Non-U.S. Citizen	My identity may be released to: ☐ Any employer ☐ All but present employer

☐ WILL RELOCATE ☐ WILL NOT RELOCATE ☐ OTHER ____________________

EDN Databank

A DIVISION OF PLACEMENT SERVICES LTD., INC.

265 S. Main Street, Akron, OH 44308 216/762-0279

© 1989 Honeywell Inc.

HONEYWELL: OPENING THE DOOR TO AVIONICS TECHNOLOGY OF THE 90s.

Honeywell in Phoenix offers a variety of career opportunities in our Commercial Flight Systems Group. Our continuing growth has created the following positions:

Systems Design Engineer — In this area, you will be involved in guidance and control systems analysis and hardware/software design trade-offs. Specification designs, including guidance, navigation and control algorithm development, as well as systems integration and installation, flight test and customer liaison activity, are a part of these positions.

System Software Development — This area involves development of flight software for advanced guidance and control systems for aircraft using modular and structured programming techniques. You will be involved with algorithms and development of real-time programs in both assembly (8086 family Z8002, 68000) and high order languages such as Pascal, "C," Ada and PLM/86, with subsequent hardware integration.

Electronics Engineering — These positions involve the development of new processor/bus architectures and specifications to support fault tolerant/redundant airborne applications.

Display Systems — These positions offer systems, software and hardware opportunities with CRT/LCD display technology. You should be familiar with digital hardware design and/or real-time programming. Systems functions include overall system definition, design and customer interaction.

To qualify for the positions listed above, you should have a BSEE or a BSCS degree and at least three years of experience.

Quality Engineering — To qualify for this position, you should have a BS degree in an engineering curriculum. A minimum of two to five years of experience in quality engineering/assurance, reliability and/or product engineering is required. You should have computer applications experience. Customer interface experience is preferred.

Additional opportunities are available in:

- CRT/LCD Display Technology
- Avionics Systems Simulation
- CAE Engineering (Apollo Mentor Systems)
- Artificial Intelligence
- VAX Systems Administration
- Fiber Optic Pressure Sensors
- EMI/HERF
- Software Tools Development

Make a career move. Honeywell offers you a competitive salary and benefits package. All new employees are required to successfully complete a drug screening test. Send your resume and salary history, in confidence, to Honeywell, Commercial Flight Systems Group, Professional Employment (EDN-E845), P.O. Box 21111, M/S I-17C, Phoenix, AZ 85036.

Honeywell

HELPING YOU CONTROL
YOUR WORLD

Equal Employment Opportunity/Affirmative Action Employer
U.S. citizenship required for some positions

With a career at Motorola Cellular, we see no end in sites.

Stretching from the U.S. throughout the Far East, Latin America and Europe, Motorola cell sites cover the world. In fact, the company that pioneered cellular communications is now outdistancing all competitors combined. We're bringing the worldwide telecommunity closer and paving the way for even greater breakthroughs...like our patented four-cell reuse plan that supports more voice channels with fewer cell sites.

And with just 1% of the global cellular market developed, the opportunities at Motorola Cellular have just begun. We're developing the most advanced software, switching equipment and radio telephone exchanges. We're constantly modifying, updating and simplifying systems while enhancing RF sector-sharing capabilities.

Flexibility, capability and expandability...that's what Motorola Cellular can offer its customers...and your engineering career. If you want a career as dynamic as our growth, set your sites on one of the opportunities on the opposite page.

We offer an attractive salary, a comprehensive benefits package and opportunities for professional growth. For immediate consideration, please send your resume to: Supervisor, Professional Recruitment, Motorola Inc., Cellular, 1501 West Shure Drive, Arlington Heights, IL 60004. Or FAX your resume to: (708) 632-5717 (our 24-hour FAX line). To access our On-Line Career Network from your PC, dial (508) 263-3857, press return twice, and key in password LEGACY. We are an equal opportunity/affirmative action employer.

MOTOROLA

Cellular Subscriber Group

Radio Telephone Systems Group

1990
1991
1992
1993
1994

SOFTWARE: Real-time software development using C, UNIX*, Pascal, Ada, assembler and structured design; experience in software quality, metrics, or testing; CASE software tools (Sun, Apollo); design, programming and system debugging for telephone digital switching or data communication systems; assembler and high-level structured languages; hardware diagnostics; object oriented design, C++; software development tools such as Teamwork and Interleaf; ASN.1 (Abstract Syntax Notation); data communications protocols (CCITT #7, OSI, X.25, X.75, PAD, LAPB, LAPD, Ethernet, ISDN, CCITT V series modem, group 3 fax); modeling and simulations (GPSS, SIMSCRIPT and other simulation tools). BSEE/BSCS/BSCE or equivalent. Respond to Dept. SW.

ELECTRICAL/COMPUTER: Analog and RF circuit design, receiver or transmitter RF circuits; LCD display technology, acoustics, and 8-bit microprocessor software; infrared and fiber optics; low speed data; digital modulation; 900 Mhz RF power amplifier design with hybrid or microstrip circuitry; RF device development with device vendors; parallel and/or push-pull RF amplifier design at 900 Mhz or UHF; A/D and D/A convertors; RF propagation; passive and active filter theory; microwave antenna design; UL, EMI and RFI requirements; HP 3062 test system; HP 9000; digital hardware, microprocessor applications and interfaces; digital switching technology; firmware development methodology; PCM and digital telephony; digital signal processing; ASIC design; LAN systems, PSTN standards, ISDN standards, processor architectures, high-speed logic; 16-bit MPU design practices, programmable logic; digital modulation synchronization, adaptive signal processing, viterbi algorithm and MLSE, decision Feedback equalizer; convolutional code and linear block code, speech coding, echo cancellation, encryption; CAE techniques for digital hardware design using Mentor Graphics, etc.; data communications protocols (CCITT #7, OSI, X.25, X.75, PAD, LAPB, LAPD, Ethernet, ISDN, CCITT V series modem, group 3 fax); computer network management/administration (Apollo, Sun, Mentor Graphics, AppleTalk). BSEE/MSEE/ BSCE/BSCS or equivalent. Respond to Dept. EC.

MECHANICAL: Electronic packaging; CAD, CV CADDS 4X; materials selection and geometric tolerances and dimensioning; extruded metal; injection molded plastics; life test procedures and factory introduction and support; plating materials and processes; structural analysis modeling; die casting and sheet metal stampings; thermal management. BSME/ MSME or equivalent. Respond to Dept. ME.

SYSTEMS: Radio/cellular communication systems engineering; RF propagation prediction methods; PSTN traffic planning; telephone network, interconnection and telecommunication industry standards; microwave system design and equipment engineering; telephone switching systems; software programming skills. BSEE/BSCE/ BSCS or equivalent. Respond to Dept. S.

*Registered trademark of AT&T.

Our breakthroughs are heard around the world.

Quality design and advanced technology. Because lives depend on it.

More than a name, Pacesetter is our way of viewing our mission and applying technology. Beginning with the first internal cardiac pacemaker, to the application of advanced NASA technology to medical science, to our present programmable, dual chamber pacemaker, the tradition continues with our commitment to up-to-the-minute life-assisting and life-critical biomedical technology.

Proud of these technological achievements, our greatest satisfaction is knowing our products have enriched and extended the lives of millions. In fact, the very first pacemaker recipient, Arne Larsson, is still enjoying an active lifestyle in his 70's.

With the support of the multi-billion dollar Siemens Company, we're totally committed to living up to our name, and fulfilling the promise of quality made to the people who depend on our products every day.

We invite you to find out about the career opportunities available to electronic engineering professionals in a variety of disciplines. In addition to our desirable Southern California location, we offer competitive compensation and benefits including company-paid retirement, 401(k), tuition reimbursement, vision care and a choice of dental/health plans. Send resume (NO PHONE CALLS, PLEASE!) to: **Greer A. Brooks, Employment Representative, Dept. EDN, Pacesetter Systems, Inc., 12884 Bradley Avenue, Sylmar, CA 91342.** Equal Opportunity Employer.

Pacesetter® Systems, Inc.
A Siemens Company
Where Reliability is a Way of Life®

If you're looking for work, just look here.

EDN Magazine Edition
News Edition

LEADTIME INDEX

Percentage of respondents

ITEM	Off the shelf	1-5 weeks	6-10 weeks	11-20 weeks	21-30 weeks	Over 30 weeks	Average (weeks)	Last month's average (weeks)
TRANSFORMERS								
Toroidal	7	22	71	0	0	0	6.3	7.4
Pot-Core	14	8	57	21	0	0	8.0	8.0
Laminate (power)	7	29	57	7	0	0	6.5	6.2
CONNECTORS								
Military panel	10	40	40	10	0	0	5.9	8.4
Flat/Cable	13	48	35	4	0	0	4.8	4.7
Multi-pin circular	7	43	50	0	0	0	5.2	4.4
PC (2-piece)	14	57	29	0	0	0	4.0	4.4
RF/Coaxial	14	57	21	8	0	0	4.6	4.0
Socket	10	61	24	5	0	0	4.5	3.5
Terminal blocks	15	55	30	0	0	0	4.0	4.7
Edge card	14	45	41	0	0	0	4.6	4.3
D-Subminiature	22	52	26	0	0	0	3.6	4.3
Rack & panel	9	46	45	0	0	0	4.9	5.4
Power	0	62	38	0	0	0	4.8	4.5
PRINTED CIRCUIT BOARDS								
Single sided	8	42	46	4	0	0	5.5	2.2
Double sided	6	45	45	4	0	0	5.5	6.0
Multi-layer	5	35	50	5	5	0	7.0	7.1
Prototype	7	78	8	7	0	0	4.0	6.5
RESISTORS								
Carbon film	56	20	20	4	0	0	2.8	3.1
Carbon composition	38	29	29	4	0	0	3.8	4.0
Metal film	38	21	37	4	0	0	4.2	3.3
Metal oxide	27	27	46	0	0	0	4.4	3.8
Wirewound	14	32	49	5	0	0	5.6	5.4
Potentiometers	20	36	24	20	0	0	6.0	5.7
Networks	11	50	33	6	0	0	5.0	6.7
FUSES	40	35	25	0	0	0	3.0	3.1
SWITCHES								
Pushbutton	19	48	33	0	0	0	4.0	3.9
Rotary	18	46	24	12	0	0	5.1	5.0
Rocker	22	34	35	9	0	0	5.2	3.6
Thumbwheel	0	44	56	0	0	0	5.7	4.6
Snap action	0	43	50	7	0	0	6.3	7.6
Momentary	0	53	47	0	0	0	5.3	6.8
Dual-in-line	0	44	56	0	0	0	5.7	5.6
WIRE AND CABLE								
Coaxial	31	38	31	0	0	0	3.6	3.0
Flat ribbon	11	45	44	0	0	0	4.8	3.7
Multiconductor	25	40	35	0	0	0	3.9	4.4
Hookup	36	41	23	0	0	0	3.0	1.9
Wirewrap	27	33	40	0	0	0	4.1	1.5
Power cords	28	33	39	0	0	0	4.1	4.0
POWER SUPPLIES								
Switcher	6	41	41	12	0	0	6.3	4.6
Linear	8	38	46	8	0	0	6.0	3.5
CIRCUIT BREAKERS	15	31	46	8	0	0	5.8	4.7
HEAT SINKS	14	57	21	8	0	0	4.6	4.7
BATTERIES								
Lithium coin cells	31	23	38	8	0	0	4.9	3.4
9V alkaline	27	46	20	7	0	0	4.0	1.3
Real-time clock back-up	22	33	33	12	0	0	5.4	3.1
RELAYS								
General purpose	15	45	35	5	0	0	4.9	5.3
PC board	5	59	27	9	0	0	5.3	5.6
Dry reed	0	56	44	0	0	0	5.1	6.8
Mercury	25	25	50	0	0	0	4.7	5.0
Solid state	8	31	38	23	0	0	7.5	5.4
DISCRETE SEMICONDUCTORS								
Diode	43	10	27	20	0	0	5.5	4.3
Zener	30	26	22	22	0	0	5.9	4.9
Thyristor	14	21	29	36	0	0	8.5	5.8
Small signal transistor	44	6	25	19	6	0	6.6	6.0
MOSFET	17	33	9	33	8	0	8.8	7.5
Power, bipolar	30	20	30	20	0	0	6.0	6.4
INTEGRATED CIRCUITS, DIGITAL								
Advanced CMOS	19	25	37	19	0	0	6.6	8.0
CMOS	25	33	29	13	0	0	5.3	5.0
TTL	28	28	33	11	0	0	5.1	5.0
LS	28	22	39	11	0	0	5.4	4.9
INTEGRATED CIRCUITS, LINEAR								
Communication/Circuit	11	44	12	33	0	0	7.3	4.8
OP amplifier	6	55	17	22	0	0	6.4	3.8
Voltage regulator	29	38	19	14	0	0	4.8	4.1
MEMORY CIRCUITS								
DRAM 16K	29	43	14	14	0	0	4.5	7.4
DRAM 64K	30	30	20	20	0	0	5.5	7.4
DRAM 256K	0	60	10	30	0	0	7.2	5.6
DRAM 1M-bit	0	50	0	50	0	0	9.2	6.7
SRAM 4K × 4	0	40	40	20	0	0	7.4	6.2
SRAM 8K × 8	17	58	17	8	0	0	4.3	7.2
SRAM 2K × 8	10	40	10	40	0	0	8.2	6.8
ROM/PROM	0	67	11	22	0	0	6.2	6.8
EPROM 64K	9	55	27	9	0	0	5.2	6.5
EPROM 256K	6	56	25	13	0	0	5.6	5.7
EPROM 1M-bit	0	43	0	57	0	0	10.1	7.1
EEPROM 16K	0	25	37	38	0	0	9.5	6.8
EEPROM 64K	0	37	38	25	0	0	8.0	7.3
DISPLAYS								
Panel meters	25	50	25	0	0	0	3.4	5.4
Fluorescent	11	23	33	33	0	0	8.4	8.2
CRT 12-inch monochrome	13	25	37	25	0	0	7.5	8.2
LED	19	43	33	5	0	0	4.7	4.4
Liquid crystal	6	31	50	13	0	0	6.9	10.4
MICROPROCESSOR ICs								
8-bit	25	25	44	6	0	0	5.1	6.6
16-bit	14	36	43	7	0	0	5.6	8.9
32-bit	10	30	30	30	0	0	7.9	11.3
FUNCTION PACKAGES								
Amplifier	30	20	30	20	0	0	6.0	5.4
Converter, analog to digital	20	20	40	20	0	0	6.8	7.5
Converter, digital to analog	29	0	42	29	0	0	7.8	7.5
LINE FILTERS	11	22	67	0	0	0	6.0	4.1
CAPACITORS								
Ceramic monolithic	36	28	24	12	0	0	4.6	3.9
Ceramic disc	48	20	20	12	0	0	4.0	3.7
Film	42	26	21	11	0	0	4.1	4.9
Aluminum electrolytic	27	39	7	20	7	0	6.6	6.4
Tantalum	24	47	19	5	5	0	4.9	4.9
INDUCTORS	20	53	7	13	7	0	5.9	6.4

Source: Electronics Purchasing Magazine's survey of buyers.

"**EDN MAGAZINE'S** *PRODUCT MART SECTION IS HELPING US BECOME A LEADER IN OUR MARKETPLACE."*

Raymond J. Schnorr
Vice President of Marketing
ACCEL Technologies

As Vice President of Marketing, Ray Schnorr is responsible for marketing ACCEL Technologies' affordable, professional software that meets the design needs of electrical engineers. He operates on a fixed budget and demands results. "When it comes to buying media, I'm interested in two things: performance and price. With EDN's Product Mart section, I pull high-volume sales leads and meet my budget," says Schnorr.

In nineteen months, ACCEL has sold 5000 software packages to 3000 sites. "Our ⅛-page Product Mart ads in EDN magazine are allowing us to reach our target audience." And Schnorr sees more for EDN and ACCEL. "We have significant growth plans for ACCEL, and running bigger ads in EDN will be part of the strategy to get there.

"The power and prestige of EDN is helping us grow into a leading design software company."

SOLVE DECOUPLING PROBLEMS

Rogers Corp.

CIRCLE NO 346

PCB 'DEPENDABLE'

ICP® QUARTZ ACCELEROMETERS

CIRCLE NO 341

GANG/SET (E)EPROM MULTIPROGRAMMERS

- 18-Month FREE WARRANTY and also 12-Month FREE DEVICE UPDATES.

1-800-523-1565

CIRCLE NO 342

PC488 $145

LOW COST IEEE-488 INTERFACE

WINPOINT

A FULL RANGE OF CONNECTORS & SOCKETS

CIRCLE NO 344

WE PROVIDE SOLUTIONS TO MANY INTERCONNECT PROBLEMS

CIRCLE NO 345

Mart, call Joanne Dorian, 212/463-6415

Great Designs Start With Tango-Schematic.™ Just $495.

Designs quickly come to life with Tango-Schematic's easy-to-use drawing editor and extensive component libraries. Features four line types, four text sizes, repeat and block functions, unique built-in word processor. Includes DRC, BOM, Wire List, Net List outputs and crisp plots, prints, or laserprints. The perfect front end to our popular Tango-PCB and Tango-Route board design systems.

For IBM PC/XT/AT/PS2. Just $495. Full-function Demo Package: $10. Order toll-free 800 433-7801. VISA/MC. Thirty-day money back guarantee.

ACCEL Technologies, 7358 Trade St., San Diego, CA 92121
Outside N., S. America contact IIST Technology (Australia)
Phone: 61-02-34-8499 FAX: 61-02-35-8771

CIRCLE NO 347

New! TangoTools
Eight Money-Saving
Tango Utilities—Just $295

Glide Through PCB Design.

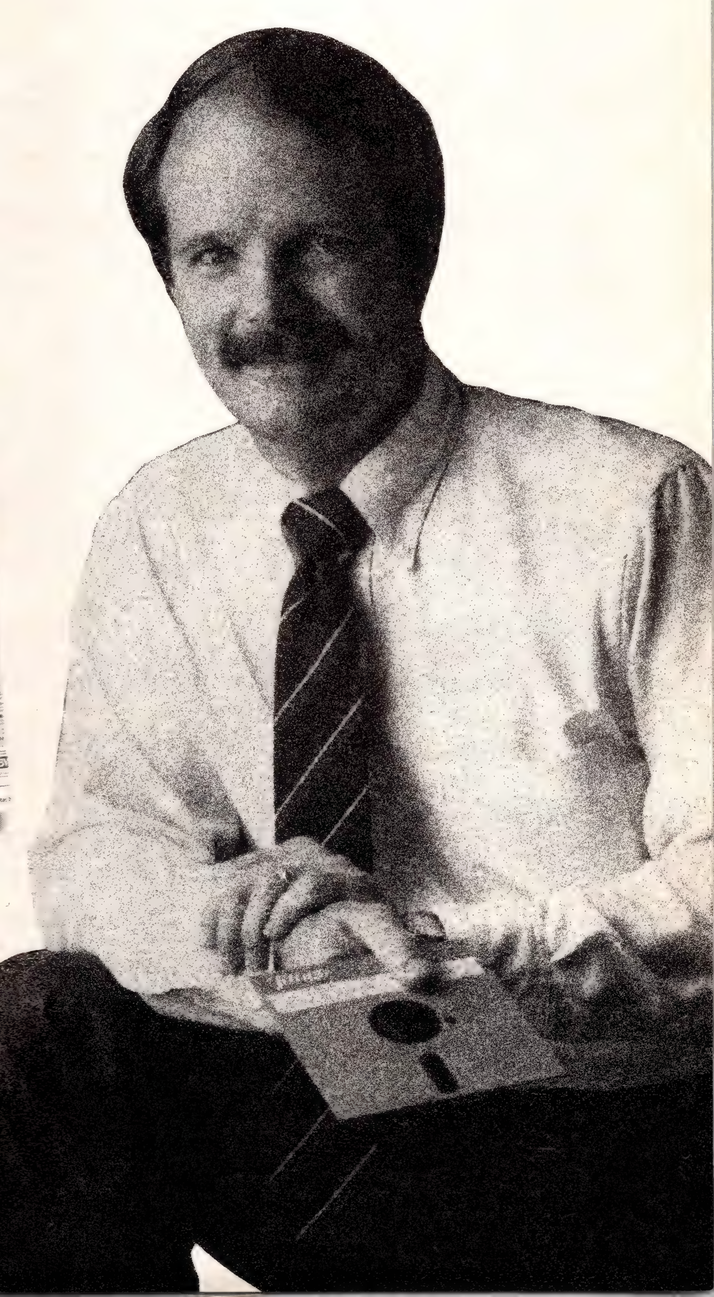
TangoPCB™ Create the toughest board designs with powerful layout software that's a snap to use. Function-rich Tango-PCB supports eight layers, 1 mil grid, OrCAD™ or Schema™ netlist input, print/plot/photoplot output, and more.

TangoRoute™ Get impressive completion rates and remarkable speed with Tango-Route, a four layer, eleven pass autorouter. **Just $495 each.**

For IBM PC/XT/AT/PS2. Compare features and you'll buy Tango. Or try full-function Demo Package, just $10. Order toll-free: 800 433-7801. VISA/MC. Thirty-day money back guarantee.

ACCEL Technologies, 7358 Trade St., San Diego, CA 92121

CIRCLE NO 348



EDN magazine works for
ACCEL Technologies. It can work for you.

EDN

Where Advertising Works

EDN's INTERNATIONAL ADVERTISERS INDEX

Abbott Transistor Laboratories Inc . . . 151
Academic Press . . . 235
ACCEL Technologies Inc . . . 235
ADPI . . . 232
Advanced Micro Devices . . . 12-13
Advance Power Supplies Inc . . . 191-192
Aerospace Optics . . . 56
ALS Design Corp . . . 186
Altera Corp . . . 50-51
Amerace Corp . . . 238
American Automation . . . 146
AMP . . . 14-15
Analog Devices Inc . . . 130-131
Analogic Corp . . . 209
Anritsu America . . . 137
Applied Microsystems Corp . . . 52-53
AT&T Microelectronics . . . 188-189
Augat . . . 83

B&C Microsystems . . . 231, 235
Beckman Industrial Corp . . . 157, 159
Bitwise Designs Inc . . . 234
Bourns Inc . . . 183
BP Microsystems . . . 234
Buckeye Stamping Co . . . 231
Burr-Brown Corp . . . 199*, C2**
BV Engineering . . . 232

Caddock Electronics Inc . . . 196
CAD Software Inc . . . 198
Cahners Exposition Group . . . 237
Capilano Computer Systems Inc . . . 233
Ceibo Ltd . . . 231
Cermetek . . . 233
Cherry Electrical Products Inc . . . 232
Comdisco . . . 194-195
Comlinear Corp . . . 216-217
Computer Dynamics . . . 204
Cybernetic Micro Systems Inc . . . 233, 236
Cypress Semiconductor . . . 48

Dale Electronics Inc . . . 25
Data I/O Corp . . . C4
Data Translation Inc . . . 63
Datel . . . 114
Daton Rogers . . . 40
Design Automation Conference . . . 31
Digelec . . . 224
DuPont Electronics . . . 213, 215, 217, 218-219

Emulation Technology Inc . . . 233
EPIX Inc . . . 234
Epson America Inc . . . 54
Equipto . . . 208 A-F
Ericsson Components . . . 179, 208
Exor . . . 236

Forth Inc . . . 163
Fujitsu Component* . . . 168
Fujitsu Microelectronics Inc* . . . C2

GCOM Inc . . . 235
Gespac Inc . . . 41
Gifts-In-Kind . . . 40
Globe Motors . . . 128
Graphtec Corp . . . 205

Harris Semiconductor . . . 230
Hewlett-Packard Co . . . 10-11, 18-19, 20
Honeywell . . . 101-106
Hypertronics Corp . . . 231

IBM-ISG Div . . . 69-71
Illinois Capacitor . . . 220
Inco . . . 175
Inmos** . . . 84D
Integrated Device Technology Inc . . . 66
Intel Corp . . . 142-143
International Rectifier . . . C3
Interpoint . . . 181
Intusoft . . . 234
IOtech Inc . . . 232
Ironwood Electronics Inc . . . 232
ITT Cannon . . . 23

J Nelson Graphics Inc . . . 234
John Fluke Manufacturing Co Inc* . . . 88-89, 162

Karl Leister Electronics . . . 114
Kepco Inc . . . 164-165

Land's End** . . . 84A
Lanier/Copier . . . 113
Lanier Voice Products . . . 42
Lattice Semiconductor Corp . . . 170
Leasametric Inc . . . 128
Lemo USA Inc . . . 233
Linear Technology Corp . . . 173-174
Link Computer Graphics Inc . . . 234
Logical Devices Inc . . . 231

Magnetek/Triad . . . 235
Marshall . . . 129
MathSoft Inc . . . 42
McGraw Hill Inc . . . 197
MetaLink Corp . . . 233
Meta Software Inc . . . 247
Micro Crystal/Div SMH . . . 232
Micro Networks . . . 207
Micron Technology Inc . . . 28-29
Micro Power Systems . . . 6
MicroSim Corp . . . 64
Mini-Circuits Laboratories . . . 26-27, 44-45, 149, 248
Mitsubishi . . . 187
Motorola Semiconductor Products Inc . . . 38-39
MWS Wire Industries . . . 155

National Instruments . . . 2
National Semiconductor Corp . . . 85, 139-141
NCR Corp . . . 228-229
NEC Corp . . . 34-37
NEC Electronics Inc . . . 35-36
Northwest Airlines . . . 30

Octagon Systems . . . 235
OKI Semiconductor . . . 97-98, 99, 100
Omation Inc . . . 232
Optoelectronics Inc . . . 236
Orbit Semiconductor . . . 4
OrCAD Systems Corp . . . 8, 233
Otto Controls . . . 226

Performance Semiconductor Corp . . . 33
Philips Components** . . . 132
Pico . . . 212, 220
Pioneer Magnetics . . . 171
Powertec, A Division of Astec America . . . 167
Precision Monolithics Inc . . . 90
Protel . . . 236

Qua Tech Inc . . . 233

RAF Electronic Hardware Inc . . . 234
Rayovac . . . 201
Raytheon Semiconductor Div . . . 86-87
Ready Systems . . . 185
Rogers Corp . . . 234, 236

SAAB** . . . 84B-C, E
Samsung Semiconductor . . . 16-17
SenSym . . . 118
Siemens Corp* . . . 132, 166, 245
Siemens Munich . . . 222-223
Silicon Systems . . . 203
Sipex Corp . . . 182
Songtech . . . 235
Spectrum Software . . . 193
Standard Research Systems Inc . . . 32

Tatum Labs . . . 236
T-Cubed Systems Inc . . . 232
Teradyne Inc . . . 46-47
Tesoft . . . 234
Toshiba America Inc . . . 144-145

Universal Data Systems . . . 158
US Industrial Distribution . . . 160

Vicor . . . 115, 211
Visionics Corp . . . 172
Vitelic . . . 184
VME Microsystems . . . 202
VTC Inc . . . 177

Wall Industries . . . 224
Wandel & Goltermann . . . 221
Wavetek . . . 3
Wintek Corp . . . 231, 236
W L Gore . . . 233

Yamaha LSI . . . 214
YSI Inc . . . 235

Ziatech Corp . . . 1
Zilog Inc . . . 43
Zitel . . . 116-117
Z-World . . . 235

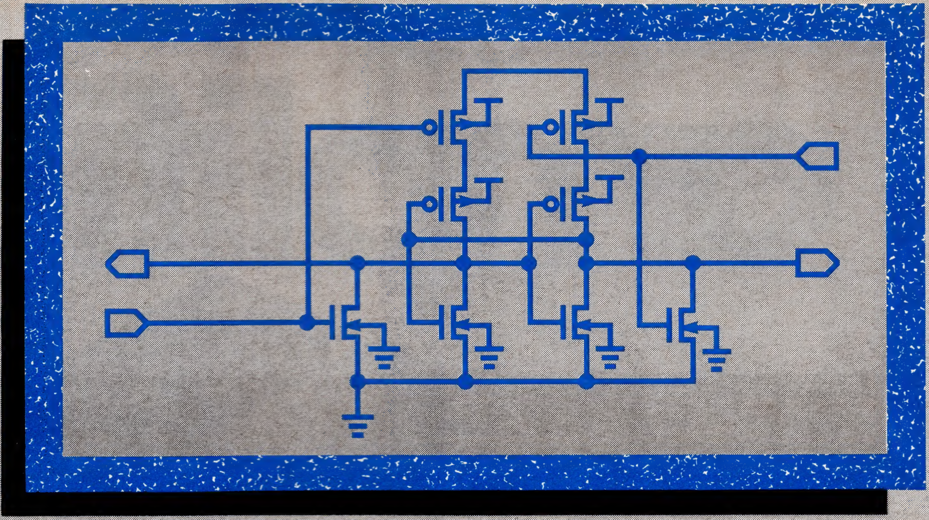
Recruitment Advertising 239-243

Honneywell Commercial Flight Systems Group
Motorola Cellular Group
Pacesetter Systems

*Advertiser in US edition
**Advertiser in International edition

This index is provided as an additional service. The publisher does not assume any liability for errors or omissions.

HSPICE



HSPICE Provides CAD Framework Independence for Design Engineers who Depend on Frames

▶ CAD Framework Dependence

The most complete set of CAD framework interfaces available. Meta-Software's HSPICE is integrated with every major CAD framework on the market. In fact, over 60% of our customers use frames, relying on HSPICE as a robust simulation engine.

The most advanced MOS, BJT and GaAsFET models and the best track record for convergence and accuracy make HSPICE the ideal choice for circuit design. HSPICE eliminates the weak link in CAD frameworks, and is the true constant in a multiple frame environment.

▶ CAD Framework Independence

CAD framework independence for circuit designers using frames. HSPICE allows engineers to use frames for designing small circuits, then batch the large circuit simulations to remote workstation servers, mainframes or supercomputers.

The result is faster turnaround time and a dramatic reduction in your design time. HSPICE is available on all major platforms, from the PC386 to the Cray.

▶ Your Technology Insurance Policy

The real world solution for your design engineering problems. For over a decade, Meta-Software has been providing HSPICE simulation support and services to circuit designers worldwide. In this fast changing world, HSPICE provides you with the clear advantage of total reliability.

For further information on your HSPICE technology insurance policy, visit us at the Custom Integrated Circuits Conference, May 13 - 15 in Boston, MA, Booth # 45-46, or contact Meta-Software.

META-SOFTWARE

Meta-Software Inc. • 1300 White Oaks Road • Campbell, CA 95008
Tel: (408) 371-5100 • Toll free: (800) 346-5953 • FAX: (408) 371-5638

CIRCLE NO. 136

rugged plug-in amplifiers

0.5 to 1000MHz from $13.95 (10 to 24 qty)

Tough enough to meet full MIL-specs, capable of operating over a wide -55° to +100°C temperature range, in a rugged package...that's Mini-Circuits' new MAN-amplifier series. The MAN-amplifier's tiny package (only 0.4 by 0.8 by 0.25 in.) requires about the same pc board area as a TO-8 and can take tougher punishment with leads that won't break off. Models are unconditionally stable and available covering frequency ranges 0.5 to 1000MHz, NF as low as 2.8dB, and power output as high as +15dBm. Prices start at only $13.95, *including* screening, thermal shock -55°C to +100C, fine and gross leak, and burn-in for 96 hours at 100°C under normal operating voltage and current.

Internally the MAN amplifiers consist of two stages, including coupling capacitors. A designer's delight, with all components self-contained. Just connect to a dc supply voltage and you are ready to go.

The new MAN-amplifiers series...
another Mini-Circuits' price/performance
breakthrough.

	FREQ. RANGE (MHz)	GAIN dB		MAX. OUT/PWR†	NF dB	DC PWR 12V,	PRICE $ ea.
MODEL	f_L to f_u	min	flatness††	dBm	(typ)	mA	(10-24)
MAN-1	0.5-500	28	1.0	8	4.5	60	13.95
MAN-2	0.5-1000	19	1.5	7	6.0	85	15.95
MAN-1LN	0.5-500	28	1.0	8	2.8	60	15.95
◇MAN-1HLN	10-500	10	0.8	15	3.7	70	15.95
*MAN-1AD	5.500	16	0.5	6	7.2	85	24.95

††Midband $10f_L$ to $f_{u/2}$, ±0.5dB †IdB Gain Compression ◇Case Height 0.3 In.
Max input power (no damage) +15dBm; VSWR in/out 1.8:1 max.

*Active Directivity (difference between reverse and forward gain) 30 dB typ.

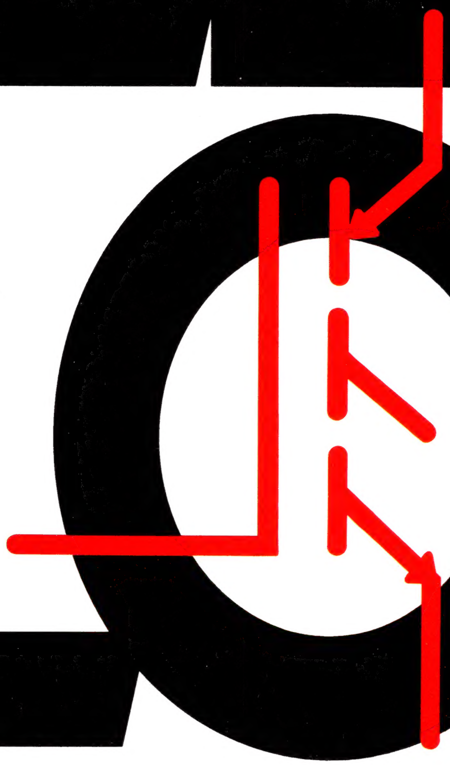
finding new ways...
setting higher standards

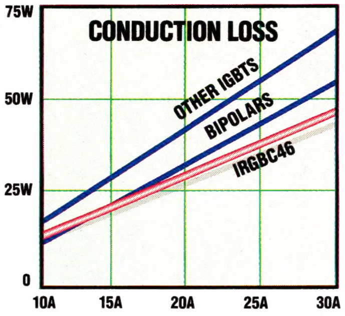
Mini-Circuits
A Division of Scientific Components Corporation
P.O. Box 350166, Brooklyn, New York 11235-0003 (718) 934-4500
Fax (718) 332-4661 Domestic and International Telexes: 6852844 or 620156

CIRCLE NO. 137

C118 REV. E

LESS LOSS



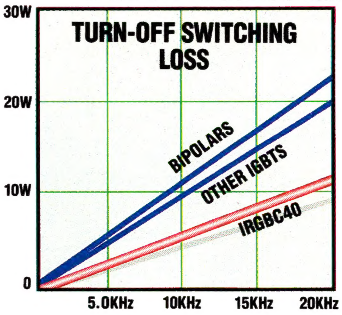


In Power Transistors, our loss is your gain. Especially when it means less conduction loss combined with greater switching speed.

International Rectifier's standard and fast IGBTs provide latch-free operation and clamped I_L ratings for rugged, reliable operation.

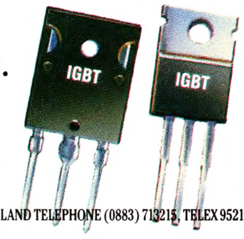
Which makes them perfect for high-voltage motor control and UPS applications. What could be better? How about extended SOA and simplified drive circuitry for lower system cost.

If all this sounds familiar, it should. Our IGBTs use the same patented technology as our world-leading HEXFETs®.



So talk to us about our new IGBTs, high-efficiency power transistors for high-voltage applications. Just call IR at 213/640-6507.

You've got nothing to lose. Except loss.



I⊗R International Rectifier

WORLD HEADQUARTERS: 233 KANSAS ST., EL SEGUNDO, CA 90245, U.S.A. (213) 772-2000. TWX 910 348-6291, TELEX 472-0403. EUROPEAN HEADQUARTERS: HURST GREEN, OXTED. SURREY RH8 9BB, ENGLAND TELEPHONE (0883) 713215, TELEX 95219

CIRCLE NO. 138

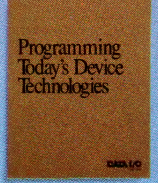
NEW
2900 Programming System

Out-of-this-world performance at a down-to-earth price.

The new 2900 Programming System brings the cost of high-performance programming down to earth. Buy only the device libraries you need today and expand capability when you need it with simple software updates.

The 2900 supports virtually every programmable logic and memory device on the market—even surface-mount packages. Its innovative technology makes programming faster, easier, and more affordable than ever before. And with Data I/O®'s industry-standard design and testing software, you can create a complete PLD development solution.

For more than 15 years, Data I/O has set the standard in device programming. Call today to learn how the 2900 is setting a new standard for both price and performance.



Call today for a FREE tutorial.

1-800-247-5700

Data I/O Corporation 10525 Willows Road N.E., P.O. Box 97046, Redmond, WA 98073-9746, U.S.A. (206) 881-6444/1-800-247-5700
Data I/O Canada 6725 Airport Road, Suite 302, Mississauga, Ontario L4V 1V2 (416) 678-0761
Data I/O Europe World Trade Center, Strawinskylaan 633, 1077 XX Amsterdam, The Netherlands +31 (0)20-6622866/Telex 16616 DATIO NL
Data I/O Instrumatic Electronic Systems Vertriebs GmbH Lochhamer Schlag 5A, 8032 Graefelfing, W. Germany, 089-85-85-80
Data I/O Japan Sumitomoseimei Higashishinbashi Bldg., 8F, 2-1-7, Higashi-Shinbashi, Minato-Ku, Tokyo 105, Japan
(03) 432-6991/Telex 2522685 DATAIO J

©1990 Data I/O Corporation

DATA I/O
Corporation

CIRCLE NO. 139